JOURNAL

OF THE

Department of Agriculture

OF

WESTERN AUSTRALIA.

Vol. 20. (Second Series) SEPTEMBER, 1943. No. 3.

Experiments with Micro Elements for the Growth of Crops in Western Australia.

IX. COPPER DEFICIENCY OF CURRANTS AT GINGIN AND ITS CORRECTION.

*L. J. H. Teakle, *H. K. Johns, and †A. G. Turton.

SUMMARY.

The unthrifty growth of currants and sultanas in certain vineyards at Gingin has been found due to copper deficiency.

Rehabilitation of the vines may be effected by copper sprays, by the use of copper fertilisers, or, preferably, by a combination of these treatments.

Vines, replanted after removal of the affected vines, make rapid growth when treated with copper.

When sampled in December, leaves of copper-deficient vines contain two to four parts per million of copper on the dry basis. Normal leaves contain about twice this amount.

No evidence of any other mineral deficiency was detected.

I.—INTRODUCTION.

For many years, fruit trees and grape vines have been grown at Gingin without any general symptoms of unusual nutritional disorders. In fact, in the early part of this century, Gingin held a reputation throughout Western Australia for the high quality of its citrus products. When farmers were able to divert their attentions more profitably to stock raising, the importance of fruitgrowing in the district waned and many orchards went out of production.

In 1933, a number of farmers in the Moondah Brook section, east of the township, planted areas of currants and sultanas. These plantings were on three of the main types of soils in the district, described by Hosking and Greaves (1936) as the Whakea sand, the Koorian sand, and the Ballingah sandy loam.

* Plant Nutrition Officer and Viticulturist respectively of the Department of Agriculture.
† Chemist, Government Chemical Laboratory.

In three of these vineyards the growth of the vines proved very unsatisfactory over considerable areas in spite of the apparent suitability of the soil with respect to texture, depth, permeability and drainage. As a result of the representations of

Fig. 1.

Six-year-old sultana vines on Mr. V. G. Rennie's property, Gingin, photographed 28th April, 1939.

Upper: Vigorous vines on Ballingah sandy loam near the drying shed. Lower: Unthrifty vines in the same row, but on Whakea sand.

Mr. L. Thorn, M.L.A., two of the authors inspected these vineyards in April, 1939, to investigate the soil conditions, as there was no evidence of disease resulting from fungus or insect attack which could be held responsible for the unthrifty growth. In fact, the vineyards had been singularly free from fungus diseases and the usual copper sprays had never been used. The significance of this will become apparent later. At this inspection, it was observed that sultanas generally made more vigorous growth than currants but, with the exception of certain favoured patches, in no instance had either variety proved satisfactory and in many cases the growth was extremely poor. Even where the vegetative growth was more satisfactory, the rooting system appeared to be very weak and subject to the attack of secondary fungus growth.

Figure 1 is a photo from the late Mr. V. G. Rennie's vineyard, Moondah, Gingin, which shows the contrast in the growth of sultana vines in different parts of the plantation. The vigorous vines may be regarded as normal for a young vigorous vineyard, but the unthrifty vines are suffering from some disability.

Figure 2 depicts the condition of the rooting systems of some of the better grown, but still somewhat unthrifty, currant vines from another portion of the vineyard which was selected for an experiment to determine the effects of various treatments on replants. These vines were dug out to make way for the new ones.

Fig. 2.
Rooting systems of six-year-old, fairly well grown currants on copper deficient Whakea sand on Mr. V. G. Rennie's property, Gingin. Note the evidence of secondary roots on the main roots and the abnormal development of adventitious roots at or near ground level.

Examination showed that, in five years, the vines, in the most severe cases, had only just reached the bottom wire about 2½ feet from ground level. The stems were little more than a half inch in thickness and the bark looked rough

and unhealthy. The canes were very short, internodal growth was severely restricted, and the wood did not mature normally. Further, the leaves were small, only slightly indented, and pale in colour due to a mild chlorosis. Where the growth of the vines was somewhat better, but still not normal, similar symptoms were observed but in a much milder form. In the portions of the vineyards where the soil conditions apparently were suitable, quite vigorous growth had been made and in some instances sultana canes were as much as 20 feet long. (Fig. 1.) In all respects these vines appeared normal and very vigorous.

Unfortunately, the bulk of the vineyards carried vines more or less unthrifty, due to some disorder. The symptoms were not definitely indicative of any particular deficiency, but in view of the discovery of copper deficiency in this area by Bennetts and Chapman (1937), the possibility of the trouble being nutritional was suspected. In consequence, normal mature leaves from vigorous and from unthrifty vines representing both currants and sultanas were selected from two of the properties. These leaves were examined spectrographically by Mr. F. E. Chapman of the Government Chemical Laboratory. His report indicated that with respect to manganese, magnesium, sodium, potassium, calcium, iron, and boron, no outstanding differences could be detected between leaves from the vigorous and unthrifty vines. There was a substantial difference, however, in the intensity of the copper lines indicating that the leaves of unthrifty vines were very much lower with respect to this element. Chemical analyses were made for ash and copper content with the results given in Table 1.

TABLE 1.

Analyses of Vigorous and of Unthrifty Sultana and Currant Vines on the Properties of Mr. V. G. Rennie and Mr. H. P. Bateman, Gingin.

Sampled 28th April, 1939.

Lab. No.	Description of Vines and Soil Type.	Ash.	Copper p.p.m. Cu dry basis.
1. V. G. Rennie—			
Sultanas :		%	
2773	Strongly growing vines on Ballingah sandy loam near drying shed	9·5	3·9
2774	Poor vines on Whakea sand	11·3	1·8
2775	Very poor vines on Whakea sand near dam ...	11·8	1·4
Currants :			
2778	Fair vines on Ballingah sandy loam	10·0	2·6
2777	Poor vines on Ballingah sandy loam	12·9	1·6
2776	Very poor vines on Whakea sand	13·5	1·7
2. H. P. Bateman—			
Currants :			
2779	Good vines growing on old rubbish pit on Koorian sand	10·4	2·8
2780	Poor vines on Koorian sand	10·5	1·2

The figures in Table 1 show that, for both currants and sultanas, the vigorous vines are considerably richer in copper than are the unthrifty ones. The percentage of ash shows no consistent variation.

This information formed the basis of a diagnosis being made that copper deficiency was the prime cause of the unsatisfactory growth in these vineyards. In order to check this diagnosis and to study means of correcting the disorder, Mr. Rennie agreed to co-operate in experimental work in his vineyard. Currants were selected for the purpose and arrangements were made to use fertiliser and spray treatments on old vines in one portion of the vineyard and, in a contiguous portion, on replants established on the sites from which the old vines had just been removed.

II.—THE EXPERIMENTS.

In much of the area selected for the experiment to determine the value of treatments in effecting recovery, the condition of the vines was such that it was thought that some years would elapse before any response could be expected. In fact, the opinion was expressed that these vines were past recovery at all, and better results would be obtained by pulling them out and replacing them with new stock. This aspect was studied in the block where the old vines were uprooted and new ones planted.

For application of the treatments, alternate rows of vines were taken so that there would be a buffer row of vines between each row under treatment. Each plot consisted of five vines and one vine was left as a buffer in the row between successive plots. Throughout the experiment, ordinary orchard practice and manuring were applied and the special treatments superimposed. At the commencement of the experiment, notes were made on the size and vigor of each vine under experimentation so that it was possible to evaluate changes occurring during the treatment.

The treatments were:—

A. *The Recovery of Old Vines.*

Treatment 1—Control, normal vineyard practice.

Treatment 2—Dormant spray, 15 lbs. of bluestone in 40 gallons of water, applied in August.

Treatment 3—Dormant spray in August plus foliage spray of Bordeaux mixture 6 : 6 : 40, applied in October and December.

Treatment 4—Four ounces of bluestone per vine applied to the soil immediately around the vine in early September.

Treatment 5—Four ounces of bluestone per vine as in (4), plus foliage sprays of Bordeaux mixture 6 : 6 : 40 in October and December.

Treatment 6—Four ounces of bluestone plus four ounces of manganese sulphate per vine in early September.

Treatment 7—Four ounces of bluestone plus four ounces of manganese sulphate plus one ounce of zinc sulphate per vine in early September.

Treatment 8—As (7) plus foliage sprays of Bordeaux mixture 6 : 6 : 40 in October and December.

B. *Replanted Vines.*

Treatment 1—Control, normal vineyard practice.

Treatment 2—Foliage sprays of Bordeaux mixture 6 : 6 : 40 in October and December.

Treatment 3—Four ounces of bluestone per vine applied to the soil around the vines in early September.

Treatment 4—Four ounces of bluestone per vine, as in (3), plus foliage sprays of Bordeaux mixture 6 : 6 : 40 in October and December.

Treatment 5—Four ounces of bluestone plus four ounces of manganese sulphate, plus one ounce of zinc sulphate per vine in early September.

Treatment 6—As (5) plus foliage sprays of Bordeaux mixture 6 : 6 : 40 in October and December.

The special soil treatments were applied in 1939, 1940, and 1941, and then discontinued. Dormant and foliage sprays were continued throughout this period and in 1942, which season marked the conclusion of the experiment.

During this period, each year the orchard received either blood and bone fertiliser, or a special mixed manure rich in potash, at the rate of 3 cwts. per acre. Each year the land was ploughed in August or September at the time of the application of the general fertiliser, and cultivated subsequently as necessary. Mature leaves were sampled in December of each year of the investigation and analysed for copper.

In December, 1939, the first year of the experiment, samples of the mature, vigorous leaves taken for copper analysis were also examined for general chemical composition. At the same time, similar samples were obtained from vines on the property of Mr. Eric Stevens of Bindoon, which were planted in the same year but which had made exceptionally vigorous growth and were proving high producers.

These leaf analyses are given in Table 2.

TABLE 2.

Mineral Composition of Leaves and Leaf Stalks from Currant and Sultana Vines grown at Gingin and Bindoon.

Vines Planted 1933 ; Leaves Sampled December, 1939.

Lab. No.	Special Soil Treatment.	Leaf Composition (on Oven Dry basis).						
		N.	P.	K.	Ca.	Mg.	Mn.	Cu.
1. *Currants*—		%	%	%	%	%	p.p.m.	p.p.m.
(A) V. G. Rennie, Gingin :								
135	¼ lb. Bluestone per vine, 1939 ...	2·41	0·19	1·10	1·66	0·41	116	2·9
136	¼ lb. Bluestone per vine, 1939 ...	2·32	0·17	1·19	1·75	0·34	90	2·9
137	None	2·43	0·23	1·12	1·97	0·40	96	3·1
138	None	2·29	0·22	1·09	2·00	0·38	88	2·5
(B) E. Stephens, Bindoon :								
142	None	2·75	0·17	1·20	1·96	0·49	73	9·8
143	None	2·67	0·16	1·17	2·19	0·42	38	7·9
144	None	2·85	0·16	1·10	2·44	0·47	45	9·9
2. *Sultanas*—								
(A) V. G. Rennie, Gingin :								
133	¼ lb. Bluestone per vine, 1939 ...	2·46	0·23	1·32	1·17	0·67	113	2·1
134	¼ lb. Bluestone per vine, 1939 ...	2·25	0·18	1·22	1·34	0·66	166	2·9
131	None	2·32	0·26	1·32	1·88	0·72	160	3·8
132	None	2·31	0·21	1·18	1·52	0·56	164	5·4
(B) E. Stephens, Bindoon :								
139	None	2·48	0·19	1·39	1·88	0·49	120	8·1
140	None	2·63	0·17	1·61	1·98	0·42	70	7·9
141	None	2·52	0·17	1·58	1·78	0·43	46	7·5

These data show that the Gingin samples are exceptionally low in copper as compared with those obtained from Bindoon but the other elements are similar in concentration. Minor variations occur as, for instance, with respect to magnesium, but there appear to be no consistent differences except with respect to copper.

Recovery of Old Vines.

During the 1939-40 season, no effect of treatment was observed, either on the appearance of the vines or on the copper content of the leaves.

The next growing season, 1940-41, revealed a slight improvement in the appearance of the foliage of the sprayed vines and, at pruning, the wood on these vines was found to have matured much more satisfactorily than elsewhere. Soil treatments alone had not yet affected the appearance of the vines and analyses showed that the copper content of the leaves was still low and similar to that of the control vines. Beneficial effects from the treatments, particularly where Bordeaux sprays were applied, were apparent in 1941-42.

Parallel with this improvement in appearance where bluestone had been applied to the soil was the increase in the copper content of the leaves. This treatment raised the copper content of the leaves to a concentration generally similar to that observed in the healthy vines from Bindoon. The delay in this effect is thought to be due to the very poor rooting systems of the vines resulting from the severe copper deficiency suffered. Further improvement was noted in 1942-43 and the beneficial effect of the copper treatment either as spray or as a soil treatment was established by the copper content of the leaves, yield of fruit, weight of prunings, and general appearance.

Table 3 gives the changes in copper content of the leaves from control and bluestone treated vines during the experiment.

TABLE 3.

Copper Content of Currant Leaves Sampled in mid-December in 1939, 1940, 1941, *and* 1942, *from old Experimental Vines in Mr. V. G. Rennie's Vineyard, Gingin.*

Plot.	Treatment.	Copper p.p.m. Cu. Dry Basis.			
		Dec., 1939.	Dec., 1940.	Dec., 1941.	Dec., 1942.
	Old Vines—Planted 1933—				
6	Control	...	3·9	2·7	13·0
8	Bluestone, ¼ lb. per Vine in 1939, 1940, and 1941	...	3·7	8·5	12·8
11	Control	...	2·8	2·7	9·1
12	Bluestone, ¼ lb per Vine in 1939, 1940, and 1941	...	4·1	6·4	10·3
20	Control	3·1*	3·5	1·8	5·3
		2·5*	...	...	...
21	Bluestone, ¼ lb. per Vine in 1939, 1940, and 1941	2·9	3·8	6·0	11·2
		2·9	...	...	...
26	Control	...	4·5	3·5	7·4
31	Bluestone, ¼ lb. per Vine in 1939, 1940, and 1941	...	6·4	5·2	12·5

As expected, the leaves sampled in December, 1942, from vines receiving bluestone on the soil were moderate to high in copper content, the range being 10.3 to 12.8 p.p.m. It was quite unexpected, however, to find that the leaves from the control vines, not directly treated with copper in any form and not showing obvious signs of improvement, were very much higher in copper than in previous years. The range was 5.3 to 13.0 p.p.m. of copper.

It is difficult to explain the high copper contents of the leaves from the control vines in 1942-43. As other parts of the vineyard had been sprayed for the first

* Sampled untreated buffer row adjacent plot 21.

time a few weeks earlier to control anthracnose, it is thought that slight contamination from these sources may have occurred. Cuprox was used as the spray and is very rich in copper.

The yields of fresh fruit were obtained in the 1941-42 and the 1942-43 seasons and the weight of the prunings in the latter. These data, together with a figure representing the vigour of the vines under each treatment at the commencement of the experiment in 1939, are given in Table 4.

TABLE 4.

Vigour Grade of old Vines at beginning of Experiment in 1939 expressed as per cent. of the grade given to normal vigorously-grown Vines of the vineyard, yields of fresh fruit per Vine in 1941-42 and 1942-43 Seasons, and weight of prunings in 1942-43 Season resulting from various fertiliser and spray treatments.

No.	Treatment.	1939 Season.	1941–42 Season.	1942–43 Season.	
		Vigour Grade of Vines to be Treated.	Weight of Fruit per Vine.	Weight of Fruit per Vine.	Weight of Prunings per Vine.
		%	lbs.	lbs.	ozs.
1	Control	54	9·6	5·3	17
2	Dormant spray	58	21·1	8·9	38
3	Dormant spray, Bordeaux spray	36	6·6	8·6	44
4	Bluestone fertiliser	43	11·8*	6·4*	34*
5	Bluestone fertiliser; Bordeaux spray	59	16·6	9·7	41
6	Bluestone and manganese fertiliser	67	14·9	9·1	37
7	Bluestone, manganese, and zinc fertiliser	52	12·4	8·2	39
8	Bluestone, manganese, and zinc fertiliser; Bordeaux spray	63	13·7	11·2	43

* One plot gave very little fruit or prunings in 1942–43 season. These vines had been the most unthrifty of the series in 1939 and recovery proved slow but nevertheless spectacular.

The yield data were very variable from vine to vine and, while indicating benefit from copper treatment, are not considered very conclusive. It must be remembered that these vines are now recovering from a severe setback owing to copper deficiency and many factors will influence yield of fruit. The vegetative response, shown by the weight of prunings, will be a much more certain measure of the effects of the treatments. All copper treatments have effected substantial recovery and there is an indication that the sprayed vines have attained an added advantage over those receiving soil treatments only.

The vegetative response was spectacular in the eastern part of the vineyard where the vines had been most unthrifty in 1939. Here the buffer vines receiving no copper made practically no progress in the 1939-1943 period. Vines receiving copper as a spray or as a soil treatment recovered, and, by the 1942-43 season, were more or less normal in size and appearance for ten-year old vines.

Figures 3 and 4 illustrate the response of these vines to the treatment.

Establishment of replant vines.

The vines in the replanted section, in spite of competition from the established vines surrounding them, made good progress where copper treatments were applied

either to the soil or as sprays. The controls, on the other hand, made poor growth and did not appear to be as vigorous as the old vines which had been uprooted immediately prior to their planting.

Fig. 3.
General view of the vines in the portion of Mr. V. G. Rennie's vineyard on Whakea sand where, under normal vineyard practice, currants failed to grow satisfactorily—see the front row—and where the application of copper sprays in four successive years resulted in recovery of the affected vines as indicated by the vigorous growth in the row immediately behind. Vines ten years old.

Observations were made during the period of the experiment but these cannot readily be expressed quantitatively. It is to be noted, however, that in the fourth season (1942-43) some of the treated vines were large enough to be cinctured and produced a small amount of fruit. As with the old vines, the production of wood, as indicated by the weight of prunings, is deemed to be the most reliable index of response. These weights were determined in 1942-43 and are given in Table 5.

TABLE 5.

Effect of Fertiliser and Spray treatment on the establishment of Replant Vines in the Vineyard

Replanted 1939. Prunings weighed June, 1943.

No.	Treatment.	Weight of Prunings per Vine.
		ounces.
1	Control	10
2	Bordeaux sprays	30
3	Bluestone fertiliser	32
4	Bluestone fertiliser ; Bordeaux spray	45
5	Bluestone, manganese, and zinc fertiliser	30
6	Bluestone, manganese, and zinc fertiliser ; Bordeaux spray	35

Fig. 4.

Close up of representative vines from treated and untreated rows shown in Fig. 3. Upper: Ten-year-old currant under normal vineyard practice. Lower: Recovery and growth resulting from application of copper sprays (dormant and Bordeaux) in four successive years in addition to normal vineyard practice.

Growth of the vines, as measured by the prunings, has been at least trebled by copper treatment. This increase in quantity of growth is paralleled by the improved health and more thrifty appearance of the copper treated vines and is illustrated by the contrast shown by figure 5. These photos were taken on 21st

January, 1943, and both vines represent four seasons' developments. Figure 6 shows the type of prunings obtained from control and copper treated vines. From Table 5 it seems likely that soil treatment with copper combined with a copper spray is most effective.

Fig. 5.
Four-year-old replant vines in Mr. V. G. Rennie's property, Gingin.
Upper: Plot 1—Under normal vineyard practice. Lower: Plot 4—Growth resulting from application of bluestone to the soil at 4 ounces per vine in 1939, 1940 and 1941, in addition to normal vineyard practice.

Fig. 6.

Prunings from three-year-old replant vines in 1942. (See Fig. 5 for 1943 growth.)
Left: Plot 1. Control—ordinary vineyard practice. Canes generally short and wood poorly matured.
Right: Plot 4. Bluestone ¼ lb. per vine in 1939, 1940, and 1941, in addition to ordinary vineyard practice. Canes well grown and generally vigorous. The small canes on the left are 20 in. long.

The copper content of the leaves of replant vines from control and copper treated plots is shown in Table 6.

TABLE 6.

Copper Content of Leaves from Vines Planted in 1939 after the Uprooting of the Original Crop.

No.	Treatment.	Dec., 1941.	Dec., 1942.
1	Control	3·7	13·0
4	Bluestone, ¼ lb. per vine in 1939, 1940, and 1941 ...	8·0	11·8
5	Bordeaux spray twice annually	17·8*	...
8	Control	3·9	...
11	Bluestone, ¼ lb. per vine in 1939, 1940, and 1941 ...	10·0	...
12	Bordeaux spray twice annually	34·1*	...

* Sampled leaves grown since the October spraying and immediately before the December spraying. It seems likedly that these leaves have been slightly contaminated by contact with, or dust from, the sprayed leaves.

In the 1941-42 season, the control vines were low in copper—3.7 and 3.9 p.p.m.—but the soil treatments had resulted in a normal copper content—8.0 to 10.0 p.p.m. The response was obvious. Leaves from vines sprayed with Bordeaux two months earlier were much higher in copper, probably due to slight contamination by contact with or dust from the older lower leaves. In this sampling, care was taken to select mature leaves from portions of the vines which had grown since the spraying. Leaf samples taken in December, 1942, from the control and copper treated vines shown in Figure 5, were both high in copper. This, also, is suggestive of contamination by copper-containing dust blown from parts of the vineyard sprayed earlier with Cuprox, because the control vines were still very unthrifty and gave no sign of recovery.

III.—DISCUSSION.

These investigations establish the incidence of copper deficiency as the cause of unthrifty growth of vines at Gingin.

Chemical analyses show that mature currant and sultana leaves, from country on which vigorous growth is made or where copper fertilisers have been used, contain from 7.5 to 10.0 parts per million of copper on the dry basis when sampled in mid-December. Where the vines are suffering from copper deficiency the leaves contain from 2 to 4 p.p.m. of copper when sampled at the same growth stage. These figures are in close agreement with analyses given by Oserkowsky and Thomas (1938) for leaves of pears, and by Dunne (1936) for leaves of apples, affected by copper deficiency. There is evidence that leaves sampled in April—at the end of the season—are much lower in copper. However, from the more acutely deficient vines, leaves are lower in copper (1-2 p.p.m.) than from the vigorous or normal ones (2-4 p.p.m.).

The December period seems suitable for sampling leaves for diagnostic purposes. The fruit is just forming and an abundance of vigorous, mature leaves, showing no sign of senility, can be obtained.

The spectrographic and general analyses indicate that the leaves are normal with respect to a considerable number of elements and that copper deficiency is the only condition at all acute.

This conclusion is supported by the experiments with various special fertilisers and copper sprays. The inclusion of manganese or of manganese and zinc with the bluestone produced no obvious benefit. Copper sprays gaxe an earlier improvement in appearance and proved equally as effective as soil treatments in relieving the deficiency. There is a suggestion that copper sprays combined with copper fertilisers are the most effective control.

The experiments showed that six year old vines, very unthrifty on account of copper deficiency, were renovated by the copper treatments but 3 to 4 years elapsed before the recovery was substantial. It is thought that deterioration of the rooting system due to the deficiency, rendered the vines incapable of rapid response.

The replanted vines showed vigorous establishment on the sites of the old vines when treated with copper. This establishment was effected although planted in rows adjacent to vines already in their sixth year. Apparently, owing to copper deficiency, the competition from these older vines was negligible.

The copper deficiency affects the growth of the vine generally. The rooting system is poor and the annual production of adventitious roots at or near the surface of the soil is characteristic. The stem growth is restricted and the bark rough and unhealthy. Leaves are small and pale in colour, the canes are short

with short internodes, and the wood matures badly. Fruiting is shy and the quality poor.

Copper deficiency is readily controlled by annual copper sprays and by the use of copper-containing fertilisers. As a soil dressing, one application of bluestone at the rate of 1 cwt. per acre should be adequate for several years.

The authors wish to express their appreciation of the assistance of the late Mr. V. G. Rennie, who made available part of his vineyard for the work and incurred considerable expense in the replanting of portion of the experimental area.

LITERATURE CITED.

Bennetts, H. W., and Chapman, F. E., 1937: *Aust. Vet. Jour,* 13 : 138.
Dunne, T. C., 1938: *Jour of Agric., West. Aust.,* 15 : 120-126 and 381-382.
Hosking, J. S., and Greaves, G. A., 1936: *Jour. Roy. Soc. West. Aust.,* 22 : 71-112.
Oserkowsky, J., and Thomas, H. E., 1938: *Plant Physiol.* 13 : 451-466.

Breech and Tail "Strike" in Sheep.

MULES OPERATION TECHNIQUE AND OTHER FACTORS.

W. L. McGARRY, Sheep and Wool Adviser.

The predisposition of sheep to crutch strike is due to the definite physical character of the sheep itself and it is now well established that the conformation of the breech is one of the main factors in predisposing sheep to crutch strike.

In dealing with the problem of blow-fly control the first necessary step is to remove or reduce the inherent predisposition of sheep to "strike." Sheep are not struck by accident or chance; they are struck deliberately because by nature and conformation they are predisposed towards fly strike. It follows that the more faulty the breech conformation the greater are the chances of sheep becoming struck.

Fly strike is a condition of parasitism and effective strike cannot occur in the absence of free moisture at the site of deposition of eggs by the fly. Generally it can also be said that serious fly strike cannot occur unless the primary fly is present in sufficient numbers.

There are three ways of removing or reducing the natural or inherent predisposition of sheep to strike. They are:—

1. Selective breeding.
2. The Mules operation.
3. The "long" tail.

While selective breeding, or gradually breeding away from wrinkly breeched sheep, can achieve much, it is obvious that this method offers little *immediate* relief from the devastation of fly strike. Although as a long range policy it should not be neglected a note of warning is sounded here of the danger of breeding light plain sheep. The reversion to lightness has always to be fought and no grower desires to lighten the wool on his sheep. It is interesting to point out here that research workers have made the almost incredible finding that merino wool fibres, plus their sweat and fat glands, occupy only from 5 to 8 per cent. of the skin area on a sheep and therefore at least 92 per cent. of the skin is bare. In the medium wool types, the evidence appears to indicate that we have to guard against a reversion to "plain and light" in sheep with too tight a skin that fits like a glove.

The fibres on such sheep also invariably receive very little protection from dust and weathering. Of course the type of sheep with a skin that tends to looseness and slight breech pucker should not be confused with the wrinkly and wrinkly short fatty-woolled types which are an abomination and always to be avoided. The aim should be a warp wool showing quality and desirable characteristics and processing into a good weight of *scoured product* on a well set and compact sheep. Given this, we should not worry unduly regarding some breech pucker.

Fig. 1.
Sheep before treatment.

The value of the second method, that is making the breech of the sheep plain artificially by the Mules operation, is undoubted. The Mules operation is now regarded by research workers as the biggest single means so far discovered towards control of breech strike and breech strike accounts for 90 per cent. of the losses due to blowfly strike. The Mules operation consists of the removal of the wool bearing folds, and loose skin about the centre of the breech, and on each side of the vulva, which are both most likely to be soiled by urine or dung. By this removal the skin is tightened and better drainage is achieved. The Mules operation does not involve the removal of *all* the folds about the breech, or tail. The operation is not harmful to the sheep and can be performed on sheep of any age and the effect is permanent for the life of the animal.

In performing the Mules operation the aim is to achieve—

1. The removal of the wrinkle and loose skin from the crutch of the sheep.
2. The stretching out of the bare area below the tail.

Fig. 2.
Sheep immediately after treatment.
Faults.—1. Not drastic enough. 2. Cuts start too high up from butt of tail.

These objects are achieved by drastically cutting away two crescent-shaped pieces of skin on either side of the vulva, whilst at the same time taking care to avoid cutting the bare area on either side of the organ. It is very necessary to avoid reducing the total area of the bare area by accidental cutting, as the ultimate aim is to achieve the maximum stretching of this bare area. Faulty cutting in this respect is avoided by running the shear blade just to the edge of the bare area, but not cutting into it. The cuts should taper at each end to a definite point. "Square end" cuts delay healing and what is more important invariably pucker up and heal with pockets which retain moisture and attract blowflies. The points on the cuts can be achieved by picking up the skin with the shears when starting the cut, and when finishing by bringing the shears slightly away from the body and letting them gradually run out of the skin towards the end of the cut. The aim

is to achieve two clean cuts without ragged edges. If the shears are allowed to run out of the skin before the cut is completed a second continuing cut becomes necessary. This results in an uneven or ragged edge which puckers up and delays healing. A second cut also usually causes the sheep to struggle unduly, owing to the extra momentary pain and the longer period occupied in removing the necessary skin. These factors are eliminated with one quick clean cut.

The cuts should start evenly, well down on the butt of the tail and at about the same distance from the midline of the back. If the cuts start unevenly the bare area will be drawn out unevenly resulting in the woolled skin being brought close to the vulva. It is necessary for the cuts to start at about the same level with a point and work in towards the bare area and then turn to run down the inside of the breech. The cuts should be widest about the middle and opposite the vulva. This achieves a maximum stretching of the bare area and de-wrinkling of the crutch.

It is found that beginners are invariably not drastic enough and naturally somewhat clumsy when first attempting the treatment. After correct demonstration and explanation, however, and when a few sheep have been treated this simple operation can be efficiently performed and speed is attained with practice. Examination of the sheep as they run away from the operator is advised in order to observe the faults that are being made.

To obtain maximum results from the Mules operation it is necessary to remove sufficient skin to shock anybody who is witnessing the operation for the first time.

It is definitely recommended that *all* female sheep be treated. Examination of many "plain" sheep has revealed that a large majority of them possess some surplus of loose skin in the breech. Quite apart from stretching their "bare area," it has been found that the weight of the wet (urine and rain) and dag laden wool pulls this loose skin down slightly and forms channels which retain moisture and create an attraction for the "fly" and a harbourage for maggots similar to that of definite folds or wrinkles.

It is recommended that the operation be carried out in conjunction with lamb marking. The earlier the operation is performed the greater will be the economic benefit as the protection will extend over the *whole* life of the sheep. In addition, lambs heal quicker than adult sheep and less labour is involved if the lamb is treated whilst on the rail for marking. Probably it would also be convenient to treat lambs immediately after shearing or at weaning time. If the operation is carried out at weaning time it will be necessary to crutch the sheep as the presence of wool masks the folds and prevents the operation being performed successfully. The operation can only be performed successfully on sheep that have been crutched or shorn within a week or so. If the operation is carried out at lamb marking time treat all ewe lambs. When there are older lambs with longer wool in the drop, probably due to a protracted lambing, a more efficient treatment will be achieved by crutching these lambs before operating. When treating lambs remove the folds and loose skin before the tail is docked.

The operation should not be carried out when flies are active. If circumstances preclude the treatment during cold weather when flies are absent it is advisable to operate during periods of dry weather and dry feed conditions when flies are comparatively few in numbers.

Recent experiences in the pastoral areas indicated the value of treating adult sheep when sufficient labour is available to handle the sheep. When little labour is available and to save lifting, the operator could stand outside the shed opposite

to the exit in a counting out pen in cases where the shearing shed is above ground level. Combined crutching and "Mulesing" could be carried out in this manner. In sheds of this type fast, clean treatment with a minimum of labour can be achieved by removing a square of grating (replaceable later) in a large holding or sweating pen in the body of the shed. By lowering himself in this temporary pit, the operator is in a convenient position to all the sheep which merely require catching and turning. Another suggestion to save lifting is that a small pit be dug adjacent to a crush pen in temporary sheep yards. With the operator standing in the pit he would be working level with the sheep. A floor grating or sleepers in the crush pen has proved a decided advantage under these conditions. If possible it is considered advisable not to operate in old sheep yards owing to the risk of infection due to the dust coming in contact with the wounds.

There are three important things to remember when performing this operation. Firstly, *the Mules operation can be a complete failure if it is not carried out correctly.* Secondly, *remove plenty of skin.* Thirdly, *do not perform the operation when flies are abundant and active.*

Fig. 3.
Treated sheep showing stretched bare area.

Another decided advantage of the Mules operation, is that it makes crutching much more effective and simpler to perform. Undoubtedly the period of protection given by crutching will be greater among those sheep which have been operated on than those which have not been treated. Jetting is also more effective and easier to perform on "Mulesed" sheep. The poison can reach the area required quicker and more effectively when the breech wrinkle and loose skin are removed. In addition the wrinkle and loose skin by their moisture holding characteristics

are retaining urine and by so doing are to some extent washing out and neutralising the effects of the poison. In addition the Mules operation not only greatly reduces strike, but also reduces blowfly population, because in attacking the breech of the living sheep we are attacking the *natural* and most favourable breeding ground of the primary fly, who is the arch enemy that initiates strike.

Experiments have proved that the "long" tail alone can reduce the incidence of breech and tail strike in ewes to less than half of that in animals with short tails. In the case of the wrinkled tail this can be protected by cutting to a length of about four inches when tailing as a lamb. By tailing in this way we get below the wrinkled portion of the tail and so leave a clean end instead of one with little pockets and rivers. There is also some brushing effect with the longer tail. The use of the longer tail is as above described, plus the important fact that the tail presses the wool away from the centre of the breech and, by doing so, allows for a freer drainage. Where crutching is left until the stage when many dags have formed, complaints will be made that the longer tail has the effect of increasing dags, but if crutching can be attended to at the appropriate time, and the end of the tail is properly cleaned of wool there no longer remains any doubt of the protection conferred by the longer tail. It is possible that the brushing effect referred to above can and does reduce the dag quantity in a lush season. It has been observed that the brushing effect of the longer tail does continually remove a proportion of the dung. After excretion it is obvious that a short tailed sheep is helpless in this respect. While agreeing that the long tail has the effect of making shearing and crutching slightly more difficult it is obvious that we must be prepared to give something away on some point. When giving the "long" tail it is important to leave a long skin flap underneath on the bare area with a shorter cut on the woolly surface. Tailing in this manner results in a clean bare end instead of an end carrying a tuft of wool. It is important that the "long" tail be shorn efficiently because if a tuft of wool is left on the tail, the protection can quite easily be lost.

It is suggested that tail strike can be reduced by "Mulesing" the tail. By removing a strip of skin from the tip to the butt on the top of the tail it is possible that the skin contraction will cause the bare area underneath the tail to be extended and stretched to the maximum resulting in an increase of the total area of the bare area in addition to flattening out and removing tail wrinkles. Undoubtedly the long tail also gives added protection against strike to sheep that are "plain" and not very susceptible. Quite apart from reducing crutch strike (which is undoubted) the "long" tail reduces tail wound strike owing to the smaller wound and quicker healing, resultant upon docking the tail further away from the butt. More flesh exists nearer the butt and the larger the wound the slower the healing. Although not as important as for ewes, it is considered that the "long" tail can also be given to wethers with advantage. Under station conditions at least, where many lambs are being marked quickly, confusion and faulty docking can occur when tails are being cut to two lengths. This factor is eliminated when both ewe and wether lambs are given the "long" tail. In addition to this it is possible when a wrinkly tailed wether is docked short, that the contraction of skin will cause the tail wrinkles to "pucker up" and form "pockets" suitable for strike. When docking, it is necessary to think not so much in terms of the length of the tail as of a sheep that at maturity will possess a tail that covers and is just longer than the tip of the vulva. Discretion is necessary when tailing as it is obvious that a young lamb given a tail of a measured length of four inches will have a tail longer than four inches when fully grown. Excessive burr and seed can transform a tail that is too long into a fly trap inasmuch as the seed and burr matts the wool on the end of the tail causing it to hold moisture and can lock the tail to the crutch area with resultant staining and tail strike.

Very high protection is given by the Mules operation and "long" tail, but it is limited to some extent by the increase in the length of the wool as time goes on. In view of this it is still very necessary to crutch and/or jet the sheep. *No reliance must be placed on any one measure of protection.* If possible all the measures should be adopted particularly during periods of "fly" waves. Provided it is possible to muster and handle the sheep, Mulesing, "long" tail, crutching and *thorough jetting when there is a bad fly wave* will eliminate fly trouble and pay handsome dividends for the expense and labour involved. Under pastoral conditions blowflies are bad only in good seasons, and in good seasons it should be possible to concentrate the sheep and in this manner overcome largely the mustering difficulties. Generally sheep are easier to muster in good seasons. They run in bigger mobs and are not so scattered as in poor seasons.

This concentration of sheep brings up another interesting point. It is advisable to brand or mark the more developed ewes at shearing time and when convenient, draft and place them in a convenient paddock or paddocks where they can be more easily handled and more often inspected and treated for "strike" in the event of blowfly activity. If this is done it is then possible to *do* something in the case of sheep which have not been made insusceptible by the Mules treatment in respect to selective breeding as a permanent method of reducing fly strike, *whilst still retaining desirable fleece characteristics.* In short, extremes are discouraged and the flock is kept "in the middle of the road" in respect to development by mating the plainest of the rams with the more developed ewes and the more developed rams with the plainest ewes. It is very desirable to keep more developed rams from joining with the more developed ewes. *From a wool production point of view* it is equally desirable to keep the lightest and plainest of the rams away from the lightest and plainest ewes.

Mating unlike individuals *of the same blood* (not cross breeding) is a powerful tool for *immediately* producing uniformity within a flock. In other words the aim is to achieve a larger mean of progeny that are relatively not predisposed to strike owing to their improved breech conformation.

The Apple Leafhopper.

(*Typhlocyba froggatti,* Baker.)

C. F. H. Jenkins, Government Entomologist.

The Apple Leafhopper, Apple Jassid or Canary Fly, is a native of Europe which has now become established in many of the apple growing countries of the world. It was first recorded doing damage in Australia in 1918, when orchards in New South Wales became infested. Since that time the insect has spread gradually to all the Eastern States, reaching Queensland as recently as 1938. Until very recently Western Australia was considered to be free of this pest, but in 1942 typical leafhopper injury was detected in the Bridgetown district, and insects collected were subsequently identified as true apple jassids.

DESCRIPTION.

The adult leafhopper is a small, slender winged insect measuring about 1/8 of an inch in length. Its general colour is usually yellowish green. The eyes are dark and prominent. The forewings are long and narrow and relatively thickened so as to form a protection for the almost transparent filmy and broader hind wings which are not visible when the insect is at rest.

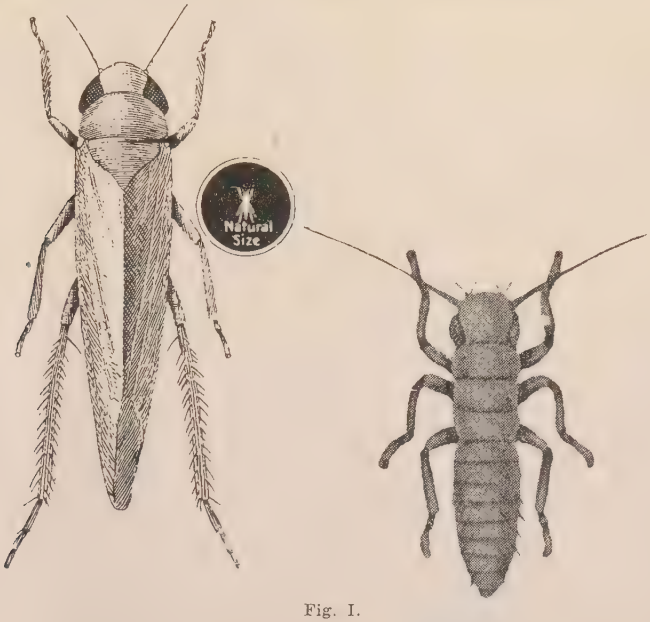


Fig. I.
The Apple Leaf-hopper. Left, adult; right, nymph.
[After Noble.]

The immature stages or nymphs are pale greenish-yellow in colour and vary in size from the minute newly-hatched individuals to the nearly full-grown nymphs which approach their parents in size. As will be seen from the illustration the nymphs have the same general form as the adults, but lack fully developed wings.

LIFE HISTORY AND HABITS.

Some details of the insect life history under local conditions have still to be worked out. As in the Eastern States, however, two generations per annum are the rule.

The spring generation emerges from over-wintering eggs which have been deposited by the previous season's females in the young bark tissues of the apple trees. Emergence may be expected under local conditions to commence about October, and to continue for several weeks. The time required to reach maturity is about six weeks and then the summer eggs are deposited in slits in mid-ribs and stalks or petioles of the leaves. The female leafhopper is provided with a horny sword-shaped ovipositor or egg-laying tube which enables her to penetrate easily the leaf tissues and the fresh season's wood in which the eggs are deposited. The situations where over-wintering eggs are laid may be recognised by what appears to be a slight blistering of the bark. These marks should not be confused with the lenticels or breathing pores of the bark, however, and a hand lens is really necessary to identify the swellings with certainty.

Although quite an active insect the apple jassid does not often fly far, and is usually only seen flitting from leaf to leaf when it has been suddenly disturbed.

TYPE OF INJURY.

In the Eastern States the leafhopper is not ranked with either the codlin moth or the fruit fly in economic importance, because it is not so destructive to fruit crops and is more easily controlled.

The leaf injury caused by the feeding of the pest is manifested by the formation of pale blotches on the leaves and a general yellowing of the foliage. In the case of heavy infestations injury may be so bad as to cause a certain amount of leaf fall. The discolouration of the leaves will naturally affect their normal functioning and may induce the formation of weak buds and so affect the next season's crop.

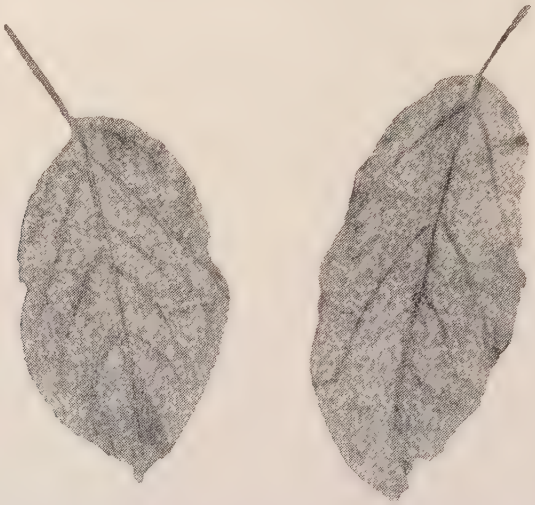


Fig. II.
Showing leaf-hopper injury to apple leaves.
[Jour. Agric., Vic.]

In addition to disfiguring the leaves, fruit may be blemished not only by the feeding marks but also by the excreta deposited by the numerous insects. The tiny specks accumulate on the fruit and especially if damped with dew or rain may cause sticky smears which require special treatment before the fruit can be marketed.

Fig. III.
Blemishes on apples caused by jassid excrement after being affected by water.
[Jour. Agric., Vic.]

Since with most species of jassids the population is greatest towards the end of the season, late varieties of apples are likely to be the most seriously affected.

Fig. IV.
Spotting caused by jassid excrement.
[Jour. Agric., Vic.]

METHOD OF DISPERSAL.

Being a winged insect dispersal from tree to tree is easily explained, but extensive flights are not habitually made. Although it is impossible to state definitely by what means the insect gained access to Western Australia, imported nursery stock is the most likely medium for its introduction. It will be remembered that over-wintering eggs are deposited in the bark tissues of the apple tree, and such eggs could easily escape detection on young apple stocks.

HOST PLANTS.

The principal host plant of this pest, as its name implies, is the apple. Pears and other fruit trees growing in infested apple orchards in the Eastern States have been observed to suffer only slight injury. In addition, the insect has been observed feeding on blackberries, hawthorn and other plants, but it is doubtful whether breeding takes place on other than apple trees.

It is worthy of note that several species of leafhoppers are very common on weeds and blackberries in many of the apple growing districts. Considerable concern on this account has been expressed by growers, but as the common blackberry and weed haunting varieties are of little economic importance and quite distinct from the apple jassid, they may be safely ignored.

CONTROL.

On account of the protected situation in which the over-wintering eggs are deposited, dormant sprays are of little use in controlling this pest. Eastern States experience has shown, however, that the following formulae applied in the summer give satisfactory results, and local experiments have borne out these findings.

1. Nicotine sulphate or Black Leaf 40, 1 pint; soap, 2 lb.; water, 80 gallons.

2. Nicotine sulphate or Black Leaf 40, 1 pint; white spraying oil, 1 gallon; water, 80 gallons.

Encouraging results were also obtained in New South Wales from the use of the following:—

Lime sulphur, 1 gallon; nicotine sulphate, ⅜ pint; water, 35 gallons.

When the nicotine sulphate is not available white oil 1 : 80 may be used alone, but is inferior to the first two formulae cited.

Kerosene Emulsion.

If for any reason proprietary insecticides are difficult to obtain, a useful contact spray for many orchard pests will be found in kerosene emulsion, which may be prepared as follows:—Boil ½ lb. of soap in a gallon of water. Add slowly two gallons of kerosene and churn violently. For use as a spray this stock solution may be broken down to one part of stock to 10 parts of water (warm if possible). Care should be taken to violently agitate the soap solution when the kerosene is being poured in, to ensure a good emulsion, otherwise some of the kerosene will remain in a free condition on the top.

In carrying out any treatments it should be remembered that the insects feed on the under sides of the leaves. The sprays depend almost entirely upon contact for their efficiency, and therefore must be applied with sufficient force and in such a manner as to thoroughly wet the foliage.

Time to Spray.

For the most satisfactory control the first spray should be applied when the majority of overwintering eggs have hatched, but before the insects have reached maturity and are themselves ready to lay. It is not possible to state the exact time of application as this will vary with seasonal and local conditions, but the end of October may be taken as a guiding date.

A second treatment three weeks after the first is necessary to deal with later hatchings, as eggs are little affected by insecticides. It is essential that the first brood be successfully controlled if damage is to be reduced to a minimum, and as the immature stages are much more easily killed than the adults the correct timing of the spray is important.

Combined Spray.

It is customary with many apple growers to apply, about November of each year, a spray consisting of arsenate of lead and white oil for the control of looper caterpillars, apple curculio, and Bryobia mite.

As already stated the exact hatching time of the apple jassid cannot be definitely forecast, but it may be assumed that nymphs will be present in November or earlier and nicotine sulphate added to the usual white oil-arsenate of lead spray will save the labour involved in a separate treatment.

The formula recommended for a general purpose spray is as follows:—

White oil, 1 gallon; arsenate of lead powder, 5 lb. or arsenate of lead paste, 10 lb.; nicotine sulphate, 1 pint; water, 80 gallons.

BIOLOGICAL CONTROL.

A tiny wasp parasite (*Anagrus armatus* Ashm.) which attacks the eggs of the jassid was introduced into Tasmania from New Zealand in 1935, and through the co-operation of Dr. J. W. Evans of the Tasmanian Department of Agriculture a consignment of wasps has been received in Western Australia for liberation in infested orchards.

Although the parasite will not eradicate the pest it is hoped that it will exercise a controlling influence and at least reduce the amount of spraying which might otherwise be necessary to keep the pest in check.

IMPORTANT.

Since the apple jassid is not as yet widely distributed in Western Australia all apple growers are advised to keep a constant watch for the pest and to forward for identification any insects of which they may be suspicious.

The most heavily infested orchards are in the Bridgetown district and as may be expected some Balingup and Donnybrook properties are also affected.

Fig. V.

Swellings in bark of apple twigs indicating the presence of winter eggs of jassids.

[Jour. Agric., Vic.]

Orchardists in clean districts should take great care when procuring young trees or scions to ensure that material is obtained from clean orchards. This applies also when obtaining parasites for woolly aphis control. Cuttings carrying parasitised aphis should only be secured from clean orchards, otherwise leafhopper eggs may be carried in the twigs.

REFERENCES.

Evans, J. W., 1940: Tas. Jour. Agric., Aug., p. 160.
Myers, J. G., 1921: Pro. Lin. N.S.W., XLVI., p. 473.
Noble, N. S., 1929: Agric. Gaz. N.S.W., Sept., p. 681.
Ward, K. M., 1938: Queen. Agric. Jour., March, p. 214.

Rubber Production in Relation to Western Australia.

A. J. Millington.

Rubber has become an essential material for both the peace and war-time economy of mechanised nations. The pre-Japanese war principal source of natural rubber was the Malay Peninsula and Archipelago which yielded 90 per cent. of the world output. Although huge stocks of rubber had been stored by Britain and America, they were obviously insufficient to meet the war requirements of the United Nations and as was the case with Germany in 1915, recourse was made to alternative sources. Minor supplies of natural rubber to the United States prior to Pearl Harbour were derived from the Amazon valley (Brazil) and Mexico (Guayule rubber) whilst synthetic rubber production amounted to 12,000 tons per annum. Energetic steps were taken by the United States Government to expand the flow of rubber from all three sources and of the 600,000 tons required for 1943, 250,000 tons will come from synthetics, which have proved by far the best source of war-time rubber. During 1944, the United States will attain a production rate of 850,000 tons of synthetic rubber per annum.

Wild guayule shrub, mixed with other plants on a ranch in Texas. The small bushy plants are guayule.

However, just as the butter industry has continued to flourish, despite the competition of a synthetic (margarine), which can be produced much more cheaply, so natural rubber is generally considered to have a place in the post war economy. Although Australia has about 15,000 acres of rubber plantation in Papua and New Guinea the yield from this area is an insignificant portion of our rubber requirements which were about 15,000 tons per annum prior to the war. Should it be deemed advisable for Australia to become wholly or partly self-sufficient in

respect to rubber production after the war, the three most promising alternatives would be plantation rubber from the tropical tree *Hevea Brasiliensis*, synthetics and Guayule.

Although the best rubber in the world still comes from the wild *Hevea Brasiliensis* of the Amazon basin, the Malayan plantations of this tree provided the greatest and cheapest source of pre-war rubber. This was achieved, however, only on the basis of a plentiful supply of cheap labour. The average output per plantation worker is one ton of rubber per annum. This is equivalent to about 40 lbs. per week so that at sixpence per lb. the worker would earn only twenty shillings. Cheap rubber can therefore only be achieved by exploiting very low-priced labour. A profitable pre-war price for plantation rubber was about sixpence per pound (Australian currency).

Under cultivation the plant looks much different. These are five-year-old cultivated plants in California.

Australia should emerge from the war with a fairly well developed chemical industry, technologically capable of producing synthetic rubber. A number of types of synthetic "rubber" material have been developed for special purposes, but the most famous is the general purpose Buna-S. This material is derived from the combination, under suitable conditions of temperature and pressure of two chemicals, butadiene and styrene. The butadiene constituent is made from either petroleum by-products or the ordinary beverage alcohol (ethyl). The cost of butadiene from alcohol is in America at least ten times that of the same material made from petroleum. The disparity in these costs is of importance to Australians since for self-sufficiency reasons, alcohol from our wheat and sugar would be preferable as a source of butadiene. The other constituent of synthetic rubber, styrene is derived from coal tar.

The average cost of the synthetic rubber now being produced in America is given as about 2s. 6d. per pound in Australian currency. Estimates of the post-war cost vary from sixpence to two shillings per pound (Australian).

For automobile tyres the efficiency of the synthetic is about 90 per cent. of the natural product, but for special purposes such as petrol pipes it is more efficient. It is usual for most purposes to mix a considerable proportion of natural rubber with the synthetic. The Germans for instance, by report, use 65 per cent. natural rubber to 35 per cent. synthetic. One effect of the synthetic rubber programme is that the United States is rapidly drinking itself "dry." The new alcohol is going into butadiene instead of beverage spirits such as whisky.

It is unlikely that Western Australia would figure as a source of either plantation rubber or synthetics and participation in any production programme would follow only on Guayule cultivation. The increasing efficiency of our rural industries as measured in terms of output per producer makes the expansion or even the maintenance of a substantial rural population increasingly difficult. Diversification of farming, particularly in those areas where wheat is now the principal crop, appears to be a possible solution to this problem. Little is known of the volume and price levels of the normal Western Australian agricultural exports to the post-war world, but it is likely that despite the expansion of synthetic rubber production there will be no great surplus of this commodity. The applications of rubber were increasing rapidly before the war and small increments in consumption per capita would absorb the current production of both natural and synthetic products.

Table I.

Country.	Pre-war consumption of rubber per 100 population.
China	3 lbs.
Russia	30 lbs.
Australia	500 lbs.
United States of America	1,000 lbs.

The Mexican rubber shrub Guayule (*Parthenium argentatum*) is a desert plant found naturally on the fans of wash material, which form at the mouth of steep mountain gullies. The area is a high plateau, from 3,000 to 7,000 feet above sea level, from which arise hills of varying size and height separated by plain-like valleys. The rainfall amounts to 7-15 inches per year and 90 per cent. of it falls during the warm months equivalent to December-April in Australia. Owing to the high elevation, temperatures vary from hot in the daytime to very cold at night and in its native habitat Guayule occurs on stony permeable soils, never on heavy clay soils.

The exploitation of Guayule as a rubber source extends over the last 40 years and since 1912 it has been raised as a domesticated plant at Salinas in California. The rubber is secreted in the stems and roots, so that harvesting necessitates destroying the plant. It is quite equal to Malayan rubber and may be used without admixture.

The Salinas climate in California is somewhat similar to that of the Western Australian wheat belt with a rainfall of 14 inches which falls during the winter months. This climate has proved satisfactory for Guayule plantations established from seedlings and was the chief research area for this crop.

Prior to Pearl Harbour 500 acres of dry land were under Guayule at Salinas. To meet the war-time demand for rubber some 50,000 acres of irrigation land have now been sown down and are expected to yield 20,000 tons of rubber by the end of 1944. Fairly large plantings have also been made in South Australia where one block of 83 acres has been sown under irrigation.

Because of the shortage of vegetables no further plantings on irrigation land are to be made in America. With the success of the synthetic rubber programme the shortage of vegetables is more acute than that of rubber.

The plants are raised in nursery beds and the seedlings transplanted when they are four to five months old. Machinery for reducing the labour requirement for these operations is in use in America where with the requisite planter a team of five men plant about one acre per hour. The plantations are inter-row cultivated to control weeds and are usually harvested, under dry land conditions, when they are four to six years old, giving yields of 1,000 to 1,800 lbs. rubber per acre. Under irrigation, growth is more rapid and the yields obtained are higher.

The seed harvesting machine works like a vacuum cleaner and is driven by a tractor.

Experiments with Guayule in Western Australia date from 1929 when a few plants were raised at the Hamel State Nursery and transplanted at Merredin Research Station and Muresk Agricultural College. At Merredin, plants survived for up to three years and attained a height of 18 inches. One of the original shrubs is still thriving at the Muresk College where it has attained a height of about 3 ft. 6 in.

In November, 1942, several pounds of seed of Guayule were received from the Council for Scientific and Industrial Research, but failed to germinate. Particulars were later received from America of the chemical treatment necessary to ensure the germination of fresh seed. Table II. gives the results of various treatments with sodium hypochlorite after pre-soaking for 20 hours.

TABLE II.

Length of Treatment.	Concentration of Hypochlorite.	Germination.
6 hours.	Water only (Control)	3%
6 „	2%	22%
6 „	4%	37%

Twenty ounces of treated seed were sown in a 100 sq. ft. nursery bed at Merredin on February 1st, 1943. About 10,000 plants were obtained from this bed, sufficient for an acre of plantation. These plants made rapid growth under irrigation and were six inches high and flowering by early April.

Later plantings at both the Merredin Research Station and the Hamel State Nursery did not give such satisfactory results. This may have been due either to lower temperatures or the reduced hours of daylight.

During early June the seedlings were transplanted to the indicator trials located at Merredin, Wongan Hills, Chapman (Geraldton), Beverley and Salmon Gums Research Stations, and also to experimental plots at Scaddan, Wyalkatchem and Kellerberrin. In these plantations the shrubs were spaced at intervals of two feet equivalent to approximately 10,000 plants per acre.

Direct sowing of the seed on the plantation site would avoid the considerable labour and expense of raising and transplanting seedlings. To obtain adequate weed control this operation can be attempted only in late autumn or winter months. Although germination was obtained from field plantings during July, 1943, in the metropolitan area and at the Avondale Research Station, the young seedlings were killed by frost. There are, however, extensive areas in the northern agricultural districts where, as frosts are not usually experienced it should be possible to establish plantations of the shrub direct from seed.

Although no reliable forecast of the economics of Guayule cultivation can be made at this juncture yields of 1,500 lbs. rubber to the acre appear to be a reasonable expectation from five to six year old plantations. At six or more pence per pound such yields should be profitable, particularly if direct sowing methods can be used. A normal farm machinery could then be used for most of the cultural operations. The rainfall incidence in the area of Mexico where Guayule occurs naturally is very similar to that of the Kimberleys in Western Australia. Trials are, therefore, being conducted at the Ord River Experimental Farm to obtain data from this area. The temperatures in northern Western Australia are, however, much higher due to the lower elevation.

A drought period each year is apparently necessary before the Guayule secretes notable quantities of rubber. An annual growing period of about five months is generally considered adequate for Guayule.

Acknowledgment is gratefully made to the Deputy Conservator of Forests, Mr. Stoate and Mr. Ross of the Hamel State Nursery and to the managers of the Research Stations and Mr. E. Langfield, for their assistance with this investigation.

The Growing of Maize for Grain.

H. G. Elliott, Agrostologist.

Climate.

Maize being indigenous to the warmer parts of either Southern Mexico, Central America or Northern South America, thrives best under warm moist conditions. It is susceptible to frosts and must be grown in regions which are free from them during the growing season. The plant is fairly drought resistant, providing the ground is in good condition and well cultivated between the plants until the tasselling period. Ample evidence has been obtained in this State to show that maize can be grown successfully for both green feed and grain in the south and west coastal and irrigation areas.

Soil.

Maize can be grown on a variety of soils, but is best suited to a deep sandy loam containing ample organic matter.

For the production of grain the critical period is the tasselling stage, and warm weather with ample soil moisture at this time is essential for heavy grain crops. These conditions can be assured by irrigation or by growing the crop on "summer moist" land.

Preparation of Seed Bed.

As maize is a deep rooter the soil should be ploughed to at least six inches for preference with a mouldboard plough which will bury all green material and trash which may occur on the surface. This ploughing should be done in the early spring so as to give the soil opportunities to mellow. The final preparation consists in obtaining a surface layer of some two inches of reasonably fine soil in which to plant the crop. It is necessary to compact the seed bed, and this is best done by double discing and harrowing, and if necessary, the use of a roller followed by a further harrowing.

Time to Plant.

Maize should be planted late enough to escape frost in the spring and early enough to miss the frosts in the autumn. October to December will be found the most suitable planting months.

Varieties.

The white seeded variety, Hickory King, is the most favoured for green feed and seed production in this State. However, small quantities of "90 Day" and Red Hogan are grown for early green feed.

Seed Selection.

For future crops farmers should select their own seed, not by picking likely looking cobs from the crib at the time of shelling, which will give fair results if conscientiously carried out, but by selecting cobs in the field, by paying attention to the type of plants and types and number of cobs produced per plant. Healthy vigorous plants with cobs that have a pronounced drooping tendency is desired. If, when mature, the cob is pointing towards the ground there will be little or no damage from water gaining access to the grain, if rains fall prior to harvesting.

Fig. 1.
Typical stalk of a prolific variety of maize showing two good ears well balanced on the stalk.
[Photo M. T. Jenkins, U.S.D.A.]

Rate of Seeding.

Maize for grain is either planted in "drills" or "hills." In this State the former method is recommended. The seed is sown in drills about 3 ft. apart with about 12 inches between seeds if under good moist conditions. With drier conditions the rows should be four feet apart with 16 inches between plants. Eight to 10 lb. of seed would be sufficient to sow an acre.

Depth of Planting.

Two or three inches deep is considered the best depth to sow, but the seed can be sown to four or five inches deep if necessary to ensure them being placed into moist soil.

Fertiliser.

It is normally recommended to use at least 3 cwts. of potato manure per acre, the fertiliser being sown in drills, but not in direct contact with the seed if this can be avoided, but owing to the present fertiliser restriction, the grower can only obtain an allowance of 2 cwt. of superphosphate and 1 cwt. of nitrate of soda per acre for this crop. Consequently, any farmer desiring to grow maize for grain would order that fertiliser which is allowed.

Method of Planting.

Single and double row maize machines for planting can be obtained. These machines are designed to sow the grain at regular intervals and are fitted with an attachment for applying the fertiliser. The machines open the furrows, drop the seed, cover, and press them into the soil in one operation.

When planting under irrigated conditions it is recommended to sow rows about four feet apart and run an irrigation furrow in between every double row.

Fig. 2.
Diagram showing a method for planting maize.
[By courtesy F. D. Richey, U.S.D.A.]

After Planting Cultivation.

This is essential for control of weeds and to increase soil aeration. The cultivation should begin soon after seed sowing and continue, if necessary, until the plants reach five to six feet high. Single or two row cultivators are recommended. The depth of cultivation should not exceed two to three inches or injury to the roots is likely to occur. Two to four cultivations should be sufficient during the growing season.

Fig. 3.
Widely spaced maize rows with cow peas growing between the rows.
[Photo F. D. Richie, U.S.D.A.]

General.

Some farmers practise the method of following on a potato field with maize and occasionally pumpkins. After the potatoes have been lifted the ground is thoroughly cultivated and packed and the maize seed sown as explained in the foregoing information. If, however, pumpkins, or a leguminous crop is grown in association, the maize is spaced at six to eight feet between rows and the other crop interrowed. Fertiliser is not usually applied, as it is considered that ample is present from the prior potato crop. It is recommended, however, that a small application of potato manure be applied at the time of planting.

Harvesting.

For grain the most common practice is to allow the crop to stand in the field until the grain is quite ripe, a condition which is shown by the husks becoming dry and hanging down. The cobs are then gathered by hand and husked in the field or in a shed.

The grain in the husks should be quite dry before storing, otherwise it is likely to heat and mould. Until thoroughly dry the cobs can be stored only in open sheds with free air circulation.

Husking and shelling can be carried out in the winter months and shelling is done best by using a maize shelling machine, which can be operated by hand or power. The grain is then graded, if necessary, and bagged for sale. It is sold in the bushel, which means 56 lb. weight. It has been estimated that about 75 lb. weight of "ears" will produce about one bushel of grain.

The "core" although of low feeding value can be ground and used as a meal.

The stalks and leaves "stover" which is left after the "ears" have been removed, contain about 1-3rd of the total food produced by the plant, and can be used, if harvested, and chaffed or shredded for feeding to horses or cattle for maintenance food during the winter.

The modern practice is to cut the crop after the grain has commenced to colour and dent, and tie the bundles, stook until the grain is dry and the stalks cured, which takes approximately five to six weeks. The cobs are then removed and the fodder stored away until required.

Notes on the Treatment of Mastitis in Dairy Herds.

In the control of mastitis, particular attention must be given to the application of measures designed to prevent the spread of infection, from animal to animal. The more rigorously these preventive measures can be applied the fewer will be the number of cases of the disease that are likely to occur. Since, however, our knowledge of the disease is still incomplete, no matter how thoroughly and energetically preventive measures are applied it will not be possible to entirely prevent the spread of infection, and new cases will, from time to time make their appearance, and must receive prompt attention.

Treatment, whatever promise it may offer must, however, be regarded as a supplementary measure. Prevention must remain the primary consideration.

The form of treatment, which in the past has generally been relied upon, has consisted of the frequent and thorough stripping out of affected quarters, together with fomentation with hot water, and massage with various stimulating liniments.

Beneficial results are frequently obtained from treatment of this kind. These results, however, are often more apparent than real, for although the signs of inflammation may subside, and the milk regain its normal appearance, the infection may persist in the quarter. This is particularly the case with chronic streptococcic mastitis, wherein the infection once it has become well established usually persists throughout the life of the animal, often to flare up periodically, and always to inflict irreparable damage, slowly but surely impairing the function of the quarter, reducing the milk yield, and finally causing it to dry up completely.

It is obvious then, that any form of treatment, in order to effect a permanent cure must succeed in destroying the infection within the udder itself. The means whereby it has been sought to bring this result about have broadly consisted of (a) the administration of drugs by the mouth, which during their excretion through the milk will destroy the infection in the udder; (b) the injection of bactericidal solutions or suspensions into the udder through the teat duct, which will come into direct contact with the organisms causing their destruction.

Of the drugs given by mouth, high hopes were held for sulphanilamide, which has given outstanding results in the treatment of certain human infections. The results obtained, however, were in the main disappointing, and since the treatment is costly it cannot generally be recommended. Amongst the solutions injected into the udder through the teat duct, the best known are the acridine derivitives, acriflavine and entozon. Both have given good results in the treatment of the less advanced cases of chronic streptococcic mastitis. Amongst other substances, for which excellent results have been claimed in the treatment of this type of mastitis, may be mentioned colloidal silver oxide, and tyrothricin, an extract prepared from a soil bacterium.

Sulphanilamide in Mineral Oil.

Quite recently a treatment, which from the view point of efficiency and simplicity of application appears to surpass all others previously employed has been described from the United States. It consists of the injection into the affected quarter of a suspension of sulphanilamide in mineral oil. The preparation of the mixture presents some difficulties, and in order to obtain a stable suspension it has to be passed through a homogenizer. Homogenized sulphanilamide-in-oil is now being prepared in this State, and may be obtained from wholesale chemists.

Highly satisfactory results have been reported in the treatment of both acute and chronic mastitis. The drug is non-irritant to the udder tissues, causing neither swelling nor pain. There is no alteration in the milk secreted, and no reduction in the milk yield. Both lactating and dry cows may be treated.

A dosage of 40 c.c. of sulphanilamide-in-oil should be injected into quarters of average size, but this may be increased to 50 c.c. if the udder is very large. This treatment should be repeated on four consecutive days, and should be carried out immediately after the morning or afternoon milking (whichever is the more convenient) after the quarter has been completely stripped out. The mixture is allowed to remain in the udder, and will be found to have been completely absorbed by the next milking. If a satisfactory response is not obtained a second course of treatment will be necessary, increasing the dosage to 80 c.c. and repeating the injections on four consecutive days.

The published reports indicate that about 70 per cent. of cases may be expected to respond to the initial course of treatment; others will require two or more courses of treatment before a cure is effected. The injections may be made by means of a teat tube attached to a syringe capable of delivering the required

amount of the suspension. The udder and teats should be thoroughly washed with an antiseptic solution, and the teat orifice swabbed with methylated spirits, before the teat tube is inserted. The teat tube and syringe should be sterilised by boiling before use.

It is scarcely to be expected that the same high degree of efficiency obtained in experimental herds will be maintained in the more severe and old standing cases encountered on commercial dairy farms. The treatment, however, is worthy of a thorough trial, and those dairy farmers desiring to employ it should consult their nearest veterinary officer. The extent to which this treatment is likely to be applied will doubtless be limited by its cost. Based on present prices the cost of the initial course of treatment is about 5s. per quarter, and for the second and subsequent courses of treatment 10s. per quarter.

Steps to Prevent or Control the Spread of Mastitis.*

There is still much to learn about mastitis in dairy cows. Attempts have been made to eliminate the infection from some herds, and in a proportion of cases these have been more or less successful. Even though our knowledge is incomplete, much more can be done to keep the occurrence of the disease down to a minimum.

In the following article are set out some of the more simple, straight-forward facts that should guide dairy farmers in their attempts to control the spread of mastitis in their herds.

The commonest form of the disease is the so-called chronic mastitis. This is due to the mastitis streptococcus, *Streptococcus agalactiae.*

Another common form, which appears to be most severe in young cows, is due to a staphylococcus, very much the same type of germ that causes boils in human beings.

Other forms, in which there is a very acute inflammation in the udder with general distress, are seen less commonly, but sometimes they may spread rapidly to the majority of the cows in a herd. These may be due to other types of streptococci or to types of bacteria found in the bowel.

CONTROL VARIES WITH TYPE OF MASTITIS.

One type of mastitis may possibly be controlled by some special method, but this method may be useless for the control of other types. This leads to confusion in the minds of dairy farmers and sometimes of control officers, especially if laboratory aid in diagnosis is not available.

Recent work shows that the bacteria which commonly cause mastitis may be carried by cows which have not developed any sign of disease. These bacteria may also be present in sheds, on utensils and possibly in yards and camping grounds. In other words, the environment may hold these bacteria, which may have a chance of entering the udder at any time, but especially during milking operations.

The majority of workers believe that the bacteria enter the udder by growing up the teat canal and then progressing until they establish themselves in the milk sinuses. The evidence suggests that the infection of the teat canal takes place most commonly while the cow is in the milking shed. A small number of first-calf heifers become infected before they have ever entered the milking shed, but they form a small minority.

* Reprinted by courtesy of the Mastitis Investigation Committee, C.S. & I.R.

PREVENT INFECTION OF TEAT CANAL.

If we concentrate, therefore, on preventing infection of the teat canal in the milking shed we should be able to prevent the most common form of infection and, further, the method should be just as effective against the mastitis streptococcus as against the staphylococcus or the other types of bacteria which can cause mastitis.

There is one additional important point to remember. A cow affected with mastitis is carrying more of the harmful bacteria than one that is not affected. It can increase the number of harmful bacteria in the environment and thus increase the chance of any other cow becoming infected.

EFFICIENT MILKING AN IMPORTANT FACTOR.

If the milk is withdrawn from the cow in the most efficient manner, mechanical injury to the udder is avoided, and time is saved which can be employed in doing essential things properly instead of in a slap-dash manner or not at all.

Every dairy farmer should try to understand the anatomy (the structure) of the udder and how milk is secreted and "let down." Only a brief mention of some of the essential features can be made here. Each quarter is a separate unit; there is no connection between the gland tissues of adjoining quarters. Each quarter is made up of the secreting tissue which may be compared in structure to a bunch of grapes. Each grape represents the cell in which the milk is formed. The milk then flows along the stalk or duct to a larger stalk or duct until the main stalks or ducts empty into the collecting cavity or milk cistern, which in turn leads into the teat canal. All this secreting and collecting tissue, or system, is supported by loose tissue containing blood vessels, nerves and fatty tissue and special muscle fibres, like those in the wall of the gut.

COW MUST "LET DOWN" MILK.

Milk is being formed or secreted all the time and gradually fills all the ducts and the milk cistern. At the end of the teat a strong muscle band keeps the teat canal closed and prevents the escape of the milk. The milk can be forced out through the canal by pressure. The pressure exerted on the teat, however, is not enough if the quarter is to be milked out quickly. Something must happen: the cow must "let down" the milk. This letting down of the milk is only an increase of the pressure within the quarter itself which forces the milk from the collecting ducts into the cistern. This increase of pressure is brought about by the contraction of the muscle fibres surrounding the cells and the ducts in the gland. What forces the muscle fibres to contract? This contraction is brought about by what is called reflex action. When the calf sucks or the milker starts to milk, the nerves in the tissues send messages to the brain which in turn sends messages to a special gland which throws into the blood stream a special substance which acts on the muscle fibres in the udder and causes them to contract and to force the milk down. This action occurs quickly and passes away almost as quickly.

CONDITIONS CONDUCIVE TO EFFICIENT MILKING.

Cows become used to being milked, and merely to bring them into the shed starts the complex mechanism which leads to the letting down of the milk. In order that this mechanism be used to the best advantage, and in order to carry out efficient milking, certain conditions must be observed and these are stated as follows:—

(a) There should be a rigid routine in the milking shed: so far as possible things should be done always in the same way and in the same order without undue delay.

(b) Especially there should be no delay in starting the milking after the udders have been washed or handled in any way. Don't wash the udders or handle them except immediately before starting to milk. Don't run down the line and wash the udders first and then go back to the beginning of the line and start the milking.

(c) The milking operation, whether by hand or by machine, should be as rapid as possible.

(d) The degree of vacuum at which the milking machine operates should be under efficient control. This is best provided by a weighted vacuum relief valve or by a spring loaded poppet type with covered spring. The machine should not be operated at a higher vacuum than that necessary to keep the teat cups on and 15 inches of vacuum is recommended as the maximum. This should not be exceeded.

If this routine is carefully followed the quarters will be rapidly and completely emptied and there will be no necessity to spend time in stripping.

After efficient milking there is no necessity to strip. The small amount of milk left in some quarters will be recovered at the next milking. If left in the quarter it will do no harm.

The physical violence of stripping, of unduly high vacuum, or of leaving the cups in position too long does harm, whereas leaving half a pound or more milk in the quarter does not.

CLEAN METHODS PREVENT INFECTION.

If we have efficient milking we have a sound basis on which to build a system to prevent bacterial infection of the udder in the milking shed. The sheds must be kept clean and free from dust. The aim must be to have the teats clean and sterile and the tea-cups of the machine or the hands of the milker also clean and sterile. It is easier to sterilise the teat-cups than the milkers' hands. The procedure should be as follows:—

(a) Wash the teats with warm soapy water. Wring out the washing cloth and dry off excess moisture.

(b) Sterilise the teats with a solution of hypochlorite. This can be made either from powder or liquid preparations on the market. The strength of the preparation is indicated by the manufacturer in terms of available chlorine, and this should be used to prepare a solution containing at most one part of chlorine to 800 parts of water or not less than one part of chlorine per 1,000 parts of water. *The solution must be made fresh at each milking* and can be applied with a cloth. Another way to apply the solution is to fill a deep (6 inches) narrow (2 to 3 inches) vessel with the solution and to dip each teat in turn into the solution which can be replaced frequently from the bulk solution kept in a bucket. Any excess fluid can be shaken from the teats: don't apply the hand or cloth in an attempt to dry.

(c) Place the sterilised teat cups in position as soon as possible after sterilising the teats.

(d) After milking each cow the cups must be cleaned and sterilised. To clean, plunge them into a bucket of warm water containing washing soda (one heaped dessertspoonful to each gallon) and raise and lower them two or three times. Shake off the water and plunge the cups into a bucket of hypochlorite solution, holding them in this for ten to twenty seconds.

CLEANSING AND STERILISING SOLUTIONS.

The hypochlorite solution will not sterilise a dirty or greasy surface. Therefore, the use as directed of warm soda water is essential. If the teats are sterilised and the cups are sterilised before use, it will be impossible to carry infection from one cow to another. The system must be rigidly observed. Fresh batches of warm soapy water, warm soda water and hypochlorite solution will be required during the milking operations. This applies especially to the soapy water for the teats and the soda water for the cups. They will have to be renewed just as often as necessary according to the number of cows. If any of these solutions become dirty they will contaminate the teats or the cups and their use will do more harm than good.

Sterilisation of the teat cups can be carried out by boiling water or steam where these are available, but heat is damaging to the rubber, especially when it is in contact with the metal.

Other types of disinfectants than hypochlorite are unsatisfactory because of odour, slowness of action on bacteria or destructive action on the rubber of the cups. Potassium permanganate (Condy's crystals) has been used by some people, but it stains most objects badly, is not as good a disinfectant as hypochlorite, and manganese is regarded as a rubber poison; that is, it spoils the rubber.

In hand-milking the same principles are followed and the milkers' hands are washed in soapy water and then in the hypochlorite solution before the milking of each cow.

The care and sterilisation of the milking machine after each milking and the regular weekly dismantling and cleaning should be carried out according to the instruction of the dairy supervisor.

HANDLING OF COWS WITH MASTITIS.

Early recognition of disease in the udder is important. A careful watch should be kept on every quarter at each milking. Slight signs of inflammation can be detected easily enough if looked for. If a quarter is swollen and feels hot it is usually infected. Sometimes there are no signs of swelling or heat in the quarter, but the milk is altered or contains clots. Clots can be detected most easily by passing the first few streams of milk through a fine wire gauze or a so-called strip cup. The use of the strip cup is strongly recommended and the test should be used on every cow once a day if possible.

Any cows showing signs of mastitis should be taken out of the line and milked last.

When purchasing cows make sure they are free from mastitis.

THE HANDLING OF THE HERD.

Calves and pregnant heifers should be kept as far away as possible from the milking herd.

Milking cows should have as much fresh green feed as possible at all times of the year.

When a cow is coming to the end of a lactation period and a decision is reached to dry-off the cow, cut down the food intake, then cease milking altogether and turn it out. Do not practise irregular milking to dry-off a cow. Very heavy producers may need special attention.

De-horn calves so as to lessen the injuries caused to udders by cows horning one another.

SUMMARY OF RECOMMENDATIONS.

(a) Keep to a rigid routine in the milking-shed; aim at rapid and efficient milking and thus remove the necessity to strip cows.

(b) Provide at least four buckets for washing and sterilising udders and teat cups. Use one bucket to contain warm soapy water for washing the udders. Use another to hold a solution of hypochlorite containing one part of chlorine to 800 parts of water. The other two buckets are reserved for the teat cups. One bucket will hold a solution of washing soda (one heaped dessertspoonful to each gallon of water); the other will contain hypochlorite solution (one part of chlorine to 800 parts of water).

(c) Wash the udder with the soapy water and renew this solution frequently before it becomes dirty. Dry out the udder with the wrung-out cloth. Sterilise the teats by washing them with, or dipping them into, the hypochlorite solution, but do not dry. At the end of the milking sterilise all cloths used for washing udders by boiling them in water.

(d) Place the clean sterilised teat cups into position as soon as possible after sterilising the teats. Remove the cups when ready, wash them in warm water containing washing soda and then dip them into the hypochlorite solution for ten to twenty seconds. They are then ready to transfer to the next cow.

(e) For hand-milking adopt the same principles. Wash and sterilise the udder: wash and sterilise the hands before milking each cow.

(f) Remove any cow with mastitis from the line and milk it last.

(g) Purchase only healthy cows free from mastitis.

(h) Keep calves and heifers away from the milking herd.

(i) When a cow is to be dried off cease milking altogether: don't milk irregularly or overstock to dry-off.

(j) De-horn calves.

Vegetable Seed Treatments.

W. P. CASS SMITH, Plant Pathologist.

Many diseases of annual crops and especially vegetables, are caused by parasites which are carried either in, or on the seed, or with the seed, in soil or other impurities.

The term "seed" may here be extended to include not only the true seed, but also plant parts used for vegetative propagation such as tubers, bulbs, and root separations, etc. Very occasionally these organisms may be visible to the naked eye. For example, when potato tubers are affected with the rhizoctonia fungus. Also their presence may sometimes be detected by discoloration of the seed which is often apparent when peas are affected with blackspot or beans with anthracnose.

Generally, however, they are present in the form of bacterial cells or fungal spores loosely attached to the surface of the seed, or as dormant fungal threads within the seed.

Because of their microscopic size, the presence of such seed-borne parasites is, in the great majority of cases, entirely unsuspected, and unless precautions are taken, seed-borne diseases are always liable to occur sooner or later.

This was well illustrated last autumn when serious outbreaks of black rot of cabbage occurred in several districts, including Osborne Park, Balcatta, Wanneroo, and Spearwood, which were attributed very largely to the planting of contaminated seed.

Seed of unknown origin or health should always be regarded with suspicion, especially in wartime, for new and serious diseases may easily be introduced with imported seed.

Various seed treatments are available which minimise this risk, and these can broadly be divided into two main groups, depending on the materials used and the purposes for which they are applied.

(1) *Seed disinfectants* are employed to kill disease-causing fungi and bacteria which are carried on, or in the seed.

(2) *Seed protectants* are applied to protect the seed and young seedlings from pre-emergence damping-off.

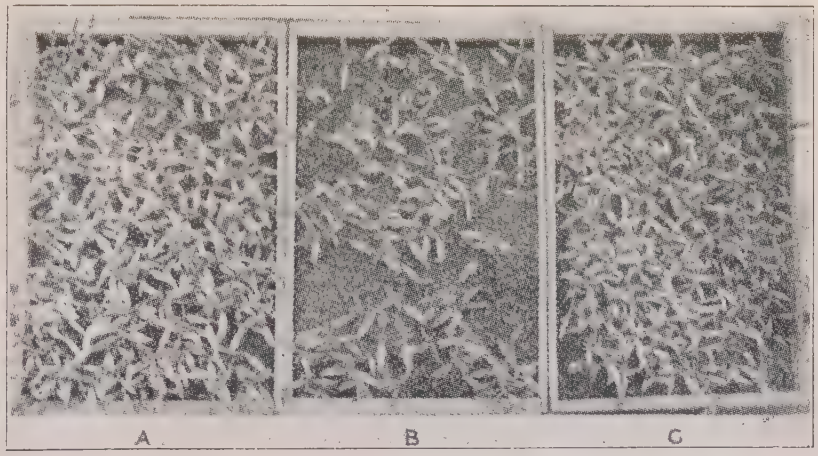


Plate 1.

Pre-emergence damping-off of tomato seedlings controlled by seed protectant dressings. A. Seed dusted with Ceresan. B. Untreated seed. C. Seed dusted with red cuprous oxide.

[After Chamberlain and Brien. N.Z. D.S.I.R. Plant Dis. Div., Bul. 1.]

Seed carrying parasitic organisms *externally* is disinfected by immersing it in fungicidal solutions, or by coating it with fungicidal dusts, and disinfectants commonly used for this purpose are solutions of corrosive sublimate or formalin, or organic-mercury dusts. To kill certain parasites which are carried *inside* the seed, heat is sometimes effectively applied, by soaking the infected seed in hot water.

The dressing of seeds with various dusts to protect them from pre-emergence damping-off has been increasingly practised during recent years. Dusts commonly employed for this purpose consist of organic mercury compounds, e.g. "Agrosan" and "Ceresan"; compounds of copper, e.g. copper oxychloride, cuprous oxide, and copper carbonate; and zinc oxide.

Pre-emergence damping-off is caused by various decay-producing organisms which may be present in the soil or carried by the seed, and which rot the seed, or young seedlings before they emerge through the soil.

This trouble may occur at all times of the year, but it is often most prevalent during winter and spring, when cold wet soil conditions lengthen the period between sowing and emergence.

With present shortages of many vegetable seeds, the use of seed protectant dressings now has an added value; for by producing better stands, considerable savings of seed may also be effected.

Plate 2.

The value of spinach-seed treatment is well illustrated by comparison of the stand in the nine cuprous-oxide-treated rows on the left with that in the five untreated rows on the right.

[After N.Y. (Cornell), Agr. Exp. Sta., Bul. 566.]

For example in a recent local experiment it was found that samples of four popular varieties of garden pea—each showing high germinable capacity in the laboratory—only gave an average emergence of 8 per cent. when planted in soil where pre-emerge damping-off was prevalent. However, when the seed was dusted with copper carbonate prior to planting the emergence increased to 53 per cent.

Seed treatments will often prevent the occurrence of diseases in the garden but they should not be relied on solely for this purpose. Rather, they should be used in conjunction with other control measures such as seed-bed disinfection, crop rotation, and general hygiene practices.

VEGETABLE SEED TREATMENTS.

Seed.	Disease.	Treatment.
		(*For smaller quantities of seed than those mentioned, see under methods.*)
Bean, French and Runner	Bacterial Blight ; Anthracnose	Discard all diseased, discoloured, and shrivelled seed.
Beets	Leaf Spot	Dip in formalin 2½ oz. to one gallon of water (= 5 tablespoonsful per gallon or 2½ teaspoonsful per pint) for 7 minutes. Rinse in water and plant at once or dry.
	Pre-emergence damping-off	Dust seed with copper dusts at 2 level teaspoons or organic mercury dusts at ½–1 teaspoon per lb.
Carrot	Pre-emergence damping-off	Dust seed with copper dusts at one level teaspoon or organic mercury dusts at ¼–½ level teaspoon per lb.
Celery	Pre-emergence damping-off	Dust seed with cuprous oxide at 1½ level teaspoons per lb.
	Early Blight ; Late Blight	Dip seed in hot water (118° F.) for 30 minutes. Spread out thinly in shade and dry quickly.
Cabbage, Cauliflower, Brussels Sprouts, Radish, Broccoli, and Turnip	Blackleg and Blackrot ...	Immerse seed in hot water (122° F.) 25 minutes for cabbage and 15 minutes for others. Spread thinly in shade and dry quickly.
	Blackrot	Immerse seed in corrosive sublimate 1-1000 strength, 30 minutes for cabbage and 20 minutes for others. Drain and then rinse for 15 minutes in clean running water. Spread to dry in shade. Prepare solution by dissolving ¼ oz. of corrosive sublimate in 1 gallon 4½ pints of water or by dissolving prepared tablets in water as recommended on the container.
	Pre-emergence damping-off	Dust seed with zinc oxide at 2 level teaspoons per lb. *Copper dusts are not recommended as they may cause injury.*
Cucumber, melons, marrow and pumpkin	Pre-emergence damping-off	As for carrot.
	Fusarium Wilt	Immerse seed in mercuric chloride (1-1000) for 5 to 7 minutes. Wash 15 minutes in clean running water and spread thinly to dry in shade.
Lettuce	Pre-emergence damping-off	Dust seed with zinc oxide at 2 level teaspoons per lb.
Onion	Pre-emergence damping-off	As for lettuce.
	Red root	Immerse seed in mercuric chloride (1–1000) for 30 minutes. Wash for 15 minutes and spread thinly to dry in shade.
	Downy Mildew	Immerse seed in hot water (122° F.) for 25 minutes. Spread thinly in shade and dry quickly.
Peas	Pre-emergence damping-off	Dust seed with copper dusts at the rate of 2 oz. per bushel (= 1 level teaspoon per lb.), or organic mercury dusts, 1 oz. per bushel (= ½ level teaspoon per lb.). *Note : Inoculated seed should not be dusted.*
	Foot Rot and Root Rot ...	Discard seed which shows brown or black marks or is badly shrivelled.

VEGETABLE SEED TREATMENTS—*continued.*

Seed.	Disease.	Treatment.
Potatoes	Rhizoctonia, Common Scab	Dip seed, unsprouted and uncut, for 10 minutes in acidulated mercuric chloride (4 ozs. dissolved in 1 quart of commercial hydrochloric acid) added to 25 gallons water. After 10 dippings, extend time to 15 minutes for each of 5 additional dippings, then discard solution. *Plant at once or dry thoroughly and store ; or* Dip in proprietary organic mercury dips according to directions on container.
Rhubarb (roots)	Foot Rot and Crown Rot	Soak roots in mercuric chloride (1–1000) for ½ hour. Wash and spread out to dry.
Spinach	Pre-emergence damping-off	As for beet.
Tomato	Pre-emergence damping-off	Dust seed with copper dusts at 1 level teaspoon or organic mercury dusts at ¼ to ½ level teaspoon per lb.
	Fusarium Wilt	Immerse seed in mercuric chloride (1–3000) for 5 minutes. Wash 15 minutes in clean running water and spread thinly to dry.

METHODS AND MATERIALS.

Dusts are applied by placing seed and dust in a Mason jar or other tightly lidded container, and shaking vigorously for several minutes, until the seeds are evenly coated. Any excess dust should be screened off.

For small amounts of seed, for example, a 6d. packet, it is impossible to recommend a definite measure of dust owing to the variable quantity of seed contained.

In such cases, a pinch of dust may be shaken up with the packeted seeds until they are thoroughly coated, and the excess dust screened off.

Hot Water Treatments.

This must be carried out with care and accuracy for the temperature required to kill a seed-borne pathogen is not much below that at which seed injury occurs. The duration of treatment is also important, for prolongation beyond the recommended period increases liability to injury. To ensure uniform temperature conditions during the steep, a large volume of water in proportion to seed should be used, e.g., ¼ to ½-lb. per 4 gallons. A suitable container, such as a kerosene tin fitted with a lid in which two holes have been bored, is nearly filled with water at the required temperature and well insulated with straw, chaff or bran, etc., either in a box or hole in the ground. The seed, tied loosely in a cheesecloth or muslin bag, is then suspended in the hot water and the tie passed through a hole in the lid.

Through the other hole, an accurate Fahrenheit thermometer is inserted.

During treatment the seed should be well agitated, but care should be taken to avoid wetting the insulating material. Boiling water should also be on hand to maintain the temperature as required. After treatment dry the seed as rapidly as possible by spreading it out thinly in the shade and stir it to promote air circulation.

Weak seed should not be treated, therefore if the quality is doubtful, a trial sample should first be tested.

Corrosive sublimate (mercuric chloride) is a *deadly poison* and it also corrodes metals. It should therefore be kept well out of reach of children and animals, and solutions should be prepared in glass, enamel, or earthenware vessels, etc.

Corrosive sublimate may be purchased in powder or tablet form from wholesale or retail chemists.

To prepare a 1:1,000 solution, 1 tablet is dissolved in 1 pint of water, or 1 ounce of the powder dissolved in 6¼ gallons of water. As the chemical is only slowly soluble in cold water, it should be dissolved in a little hot water, and water added to make the final volume.

Small quantities of solution are most conveniently prepared with tablets, but when larger quantities are required, the powder form of corrosive sublimate is cheaper.

In the latter case the most convenient method is to prepare a stock solution containing 2 ounces of the corrosive sublimate powder in 1 gallon of water, and to dilute portions of this for use as shown in the table below.

DILUTION TABLE FOR MAKING 1 IN 1,000 CORROSIVE SUBLIMATE, USING A STOCK SOLUTION OF **TWO OUNCES IN ONE GALLON.**

Stock Solution. Take amount indicated below.	Dilute with clean cold water in wooden, glass, cement, or earthenware container to final volume indicated below.
(a) ¼ pint	3⅛ pints
(b) ½ pint	6¼ pints
(c) ¾ pint	1 gallon 1⅜ pints
(d) 1 pint	1 gallon 4½ pints
(e) 1½ pints	2 gallons 2¾ pints
(f) 1 quart	3 gallons 1 pint
(g) ½ gallon	6 gallons 2 pints
(h) 1 gallon	12½ gallons

Formalin.—Commercial formalin (40 per cent. formaldehyde solution) has a pungent odour and it is irritating to the eyes. It does not attack metals.

At present this material can only be released for commercial growers but the position may change. It is useful not only for disinfecting seed against certain diseases but also for sterilising soil.

Organic mercuric dusts are sold under various proprietary names. "*Agrosan*" may be obtained from Elder Smith & Co., Ltd., or agents; "*Ceresan*" from Dalgety & Co., Ltd., or agents; and both are stocked by seedsmen.

Copper Dusts—

Copper carbonate is widely used in this State for dry pickling wheat against bunt or stinking smut. It is stocked by practically all firms with agricultural interests, by large stores, and by seedsmen. In future it may be in short supply in which case it may be replaced by copper oxychloride, or cuprous oxide.

Copper oxychlorides are sold commercially under such proprietary names as "Smutol," "Cuprox," and "Soltosan."

"Smutol" has been mainly used in the past for dressing seed wheat, and "Cuprox" and "Soltosan" as Bordeaux-mixture substitute sprays. All three substances may be used, however, for dressing various vegetable seeds.

"Smutol" and "Cuprox" are obtainable from Elder Smith and Co., Ltd., or agents, and from seedsmen, while "Soltosan" may be purchased from Paterson and Co., Ltd., or seedsmen.

Cuprous oxide was formerly sold here, as a spray material under the proprietary name of "Peronox." Limited supplies of "Peronox" and also red cuprous oxide are still available from Elder Smith and Co. and seedsmen. Seed treated with this substance, unless planted immediately, should be kept in an airtight container to avoid spoilage through oxidation.

"Hortosan" and "Aretan" are proprietary organic-mercury compounds which have been developed for quick potato dips. They are very convenient for the home gardener as the time of immersion is short, but they are probably not so effective as the longer corrosive sublimate dips.

"Hortosan" is obtainable from Elder Smith and Co., Ltd., or seedsmen, and "Aretan" from Paterson and Co., Ltd.

Stocks of these materials are at present limited and they may become more difficult to obtain in future.

Zinc oxide is a relatively mild seed dressing. It may be purchased from any chemist but as finely divided a form as possible should be used.

Precautions.

Most of the materials mentioned are poisonous in varying degrees, therefore the usual precautions should be observed when storing or applying them.

Orchard Notes.

A SEEDLING APPLE WITH PROMISE.

The following interesting report has been received from Mr. V. Cahill, Horticultural Instructor of Mundaring, and it appears that the seedling apple so much resembling Delicious may be a decided acquisition. The variety will be kept under observation, and it is hoped that it will be tried out in other districts:—

"When completing my visit to the Manjimup District on the inspection of apple scab, I chanced to visit the orchard of Mr. T. G. Trebilco, in that district. on the 4th June, 1940, and was interested to find apples which resembled the Delicious, both in appearance and flavour, still on the tree so late in the season. On examination of the tree I found it to be a seedling, 15 years or more old, bearing well.

"Being interested in the fruit I selected several scions from this seedling tree and grafted them on a tree at Chidlows in September of that year.

"The scions made good growth during the season 1941-42, and again this year, yielding over half a bushel of fruit this season. The apples were picked in the last week in May. The fruit appears to be true to the parent type at Manjimup.

"For the colour, appearance and taste, it could be classified as a late Delicious, and grown as a commercial apple. The tree is a sturdy, vigorous grower with good foliage and spur system, also a free bearer."

HOME PRESERVATION OF CITRUS JUICES.

W. J. Bettenay, Horticultural Instructor.

The value of citrus juices in our diet has been fully realised only in recent years. Quite apart from their thirst quenching qualities, which are undoubtedly great, the secret of their importance is in their high Vitamin C content. Vitamin C is essential for the prevention of scurvy. In Australia only rare cases of scurvy have occurred. Nevertheless, even if symptoms of acute scurvy are not present, it is possible for the body to be seriously affected because of the lack of Vitamin C. Children in particular may suffer from Vitamin C deficiency without exhibiting active symptoms of scurvy.

The main citrus juices in Western Australia are grapefruit, orange and lemon. Of these, orange juice is perhaps the best source of Vitamin C, but that of lemon juice is more stable in storage.

In preparing the juice, an ordinary glass cone squeezer can be used. The fruit is cut in halves and the juice extracted with a certain amount of pulp, but care must be taken not to include the oils from the outer yellow rind as these will tend to spoil the flavour. The juice may be strained or the pulp may be left in; some claim that by leaving it in the flavour is improved. The juice should be placed in an enamelled, glass or china container, and transferred quickly to glass bottles, which should be filled to within one inch of the tops and tightly corked. Brown bottles should be used as clear glass bottles allow the entry of light, which accelerates the destruction of Vitamin C.

Having obtained the juice there are two main methods of preserving it.

1. *Heat Method.*—The corks must be securely tied into the bottles with string. They are then put into a kerosene tin or copper so that when filled with water the water level comes nearly to the top of the bottles. Heat the water to 170° F., and hold at that temperature for 25 minutes. Remove the bottles and lay on their sides for several minutes, then store in a cool dark room.

2. *Chemical Method.*—The use of chemical preservatives inhibits fermentation which often causes deterioration. The following method utilises a preservative known as sodium meta-bisulphite, and it can be secured at any pharmaceutical chemist's shop. Commercial grade of this preservative costs in the region of 4/- per lb. and the quantity recommended is at the rate of one level teaspoonful to each gallon and a half of juice. The chemist probably will be able to weigh out small quantities and, if so, one gramme quantities should be used for each half gallon of the juice.

Should the chemist be only in a position to supply chemically pure sodium meta-bisulphite, the quantities recommended for commercial grade should be reduced by one third and used as follows:—

1 gramme for each ¾ gallon juice

1 teaspoonful for each 2¼ gallon juice.

The preservative should be well stirred into the juice immediately before bottling, and the filled bottles should be stored in a cool dark room.

Should sodium meta-bisulphite not be available, sodium benzoate can be used at the rate of:—

1 teaspoonful for each gallon and a half of juice

1 gramme for each half gallon of juice.

Fruit for juice should be freshly picked, and the juice after extraction needs prompt handling. All contact with metal, especially copper, should be scrupulously avoided.

Even if all precautions are taken the amount of Vitamin C in the juice decreases slowly with storage, and by the end of six months the juice is not necessarily high in Vitamin C. Orange juice loses Vitamin C faster than does lemon juice. The addition of some lemon juice to orange juice helps to retain Vitamin C.

After opening a bottle the contents deteriorate rapidly, and by the end of two weeks all Vitamin C may have gone. It is suggested that for small families, small bottles be utilised for containing the juice to avoid waste.

In addition to Vitamin C, other vitamins are to be found in citrus juices, and they include Vitamin B1, Vitamin G (B_2) and Vitamin A, all being essential to good health.

Blue Prussian or Blue Boiler Peas.

M. CULLITY, Superintendent of Dairying; H. G. ELLIOTT, Agrostologist.

Blue Prussian, or blue boiler peas were produced for export in relatively large quantities in Tasmania in the pre-war years. Since the outbreak of war with Japan and the concentration of large military forces in Australia the demand for the peas has increased.

They have several attractive features, not only for their nutritive qualities but also because they are particularly easy to transport and can be kept without spoiling for long periods. Small quantities have been used in Western Australia as loose peas, while in England they have been known over a long period as packet peas.

In preparation for use the peas are soaked for 1-2 days or longer. It has been demonstrated that by prolonging the period of soaking up to four days, by which time the peas will have sprouted and the rootlets be approaching one inch in length, the vitamin content is greatly improved. Their great value in feeding the men in the defence forces in remote areas, therefore, can be readily appreciated.

Owing to the greatly expanded requirements the mainland States were asked to endeavour to grow large areas.

Following this request a quantity of seed was imported into this State in 1942, and was made available to prospective growers on the basis of the cost of the seed being a charge against the proceeds of the crop. As the result 1,000 acres were sown, but unfortunately, owing to the unavoidable lateness of planting most crops sown in areas of light rainfall did not have sufficient moisture to allow satisfactory development of pods. In other areas where moisture conditions were favourable grub attacks were responsible for failures.

A special arrangement was also made by which the Field Pea Board guaranteed to purchase all crops on a scale graduated according to the purity of sample. While farmers were instructed to fumigate their peas as a precaution against the development of pea weevil, peas showing their presence were purchased and later sold to stock feed merchants.

Farmers were impressed with the possibilities of growing this crop, as a result of their experiences last year, and between 900 and 1,000 acres have been sown this season, although the conditions laid down by the Field Pea Board on behalf of the Commonwealth Government have required payment for seed in advance and suggest a more rigid basis of purchase.

The system of contracting with the grower to purchase his crop, if it is equal to "A" grade quality, is a guarantee that the crop if harvested and fumigated efficiently will be purchased at 15s. per bushel. There is also an implied agreement that peas of lesser quality will be purchased, providing they are capable of being cleaned to "A" grade quality. Payment for these would naturally be at a reduced price on the basis of the cleaned weight.

The specification of "A" grade is as follows:—

Prime, over ¼in.	60 %
Crinkle, over ¼in., not more than	20 %
Under ¼in., not more than	19 %
Broken, not more than	½ %
Sprouted, not more than	⅛ %
Foreign varieties, not more than	⅛ %
Foreign matter, not more than	¼ %
	100 %

It is expected that this year's experience with the crop will encourage farmers to expand their areas next year, and it appears that an opportunity will be present for this State to grow up to 3,500 acres.

Farmers are therefore requested to consider whether they can assist by making preparations on a larger scale for next season's crop.

For intending growers the following notes on the cultivation and harvesting of the crop are given.

Soil Requirements.

Well drained light to medium soils that are neutral or of low acidity are best suited to these field peas. Heavy soils rich in humus tend to produce a heavier growth of vines with comparatively fewer pods with a consequent smaller yield of seed. They will not grow well where standing water occurs or where the soil is constantly waterlogged or boggy.

Soil Preparation.

Land which has been fallowed would give best results, but early ploughing in the autumn with subsequent cultivation will give good results. It is essential that a good clean seed bed be obtained—this would tend to check the ravages of the red-legged earth mite and reduce the incident of weeds.

Time of Sowing.

This varies according to the districts, from May in medium to light rainfall areas, to end of July in the higher rainfall districts.

Rate of Seeding.

In the high rainfall areas up to 120 lbs. per acre; in the medium rainfall areas from 90 lbs. per acre, and in the lighter rainfall areas 60 lbs. per acre.

Method of Seeding.

Field peas are best sown with a grain drill either hoe or disc type. Drills should be used in preference to broadcasting the seed by hand. In any drill care must be taken to see that the feed in the drill does not crack the seed. Where a drill is not available the seed can be broadcasted by hand and covered with a spike tooth harrow or cultivator. The peas should be planted not less than 2in. deep. Laboratory tests show that good pea seed will germinate over 90 per cent., as little or no hard seeds occur in samples.

Fertiliser.

It is usually recommended to apply from 1½ to 2 cwts. of superphosphate per acre at the same time as sowing the seed.

Inoculation.

For best results these peas should be inoculated, more particularly when they are being sown on land which has not previously grown peas. The culture for inoculating can be obtained on application from the Department of Agriculture, a bottle costing 5s. will do up to four bushels of seed. It is necessary to order the culture at least two weeks before planting commences. Full instructions as to how to inoculate the seed are supplied with the culture.

Insect Pests.

In the initial stages of growth red-legged earth mite can cause a considerable amount of damage, and reduce the ultimate stand and yield of peas. Good clean fallow or good ploughing, by turning the sod completely under, will help reduce the severity of the attack. It is recommended that a good border of oats be planted round the crop to help stop encroachment of the mite from unploughed headlands.

The most serious pest of the field pea in this State is the pea weevil (*Bruchus pisorium*) and it has done more than any other pest in limiting the acreage of this crop.

Diseases.

The main disease which occurs is Black Spot. On page 42 of the June, 1943, issue of this Journal, an article written by W. P. Cass Smith, Plant Pathologist, gave information with reference to this disease and its control.

Harvesting.

The quickest and most simple method of harvesting is by a pea header attachment. In this case the peas are lifted by means of mechanical fingers on the pea front attachment of a header. The seed is threshed from the pods and the vines and empty pods are discharged at the rear of the machine.

Where these machines are not available, harvesting is usually carried out by the following method:—

It is recommended that the peas for seed be cut with a mower when the pods are nearly mature and the seed is firm. It is not advisable to wait until the vine and pods are both dry as under such conditions bleaching, loss from shattering, and weevil damage will occur. The peas are most commonly cut with the ordinary mower and wind rowed, then stacked and threshed by ordinary grain separators or threshing machines.

Control of Pea Weevil.

For farmers who are growing these peas the following notes on the control of pea weevil have been prepared by the Government Entomologist, Mr. C. F. H. Jenkins.

In order to ensure good samples of peas suitable for human consumption and canning, the following recommendations should be observed:—

1. Harvest the peas as early as possible.
2. Fumigate immediately after harvesting.
3. On no account delay treatment, as weevil grubs, although not apparent, may be feeding within the peas.
4. Use carbon bi-sulphide at the rate of from 4-20 lbs. or 2½-12½ pints per thousand cubic feet of space, according to the amount of leakage from the fumigation chamber.
5. Leave sealed for 48 hours.
6. Fumigate during warm weather when possible.

How to Fumigate.

Any airtight container of suitable size can be used for fumigation. If a room is utilised, the windows, ventilators, and all cracks must be pasted up with thick paper or otherwise sealed to prevent the escape of gas.

Tanks have been used successfully by many farmers.

A large tank may be rigged with block and tackle and lowered over stacked bags. The ground contact should be sealed with heaped up soil.

A sound tarpaulin may be used to cover stacked bags, but great care must be taken to prevent leakages.

For small quantities a sound 200-gallon tank (holds eight tipped bags) with the lid sealed with moist clay, is very effective.

Dosage Required.

1,000 gallon tank requires ¾ pint of carbon bi-sulphide.

200 gallon tank requires ¼ pint of carbon bi-sulphide.

Room 10ft. by 10ft. by 10ft. = 1,000 cubic feet, requires 2½ pints.

If leakage is suspected these dosages may be more than doubled without injury to dry seed.

Method of Application.

The gas generated is heavier than air, therefore the liquid fumigants should be placed on the *top* of the peas. It may be poured direct on to the bags or placed in shallow containers on the top of the stack. Where it is desired to treat tipped peas in a bin deeper than about 5 ft. some of the fumigant should be introduced into the centre of the mass through a long pipe.

Warning.

Carbon bi-sulphide is explosive and inflammable. Rooms should be ventilated after treatment before being entered.

Nitrate of Soda.

ITS USE IN AGRICULTURE.

L. J. H. Teakle.

"Nitrate of soda has been recognised as one of the standard nitrogen carriers for over a century." This statement was made by Dr. F. Moser of Purdue University, Indiana, in his discussion of the value of nitrogenous fertilisers for agriculture. It represents the considered conclusion of an authority on American agriculture.

Nitrate of soda is a suitable source of nitrogen for fruit trees and is extensively used for this purpose in many parts of the world. Best results are obtained by applying just before flowering.

NITROGENOUS FERTILISERS IN WESTERN AUSTRALIA.

In Western Australia, nitrate of soda does not enjoy the popularity accorded it as a fertiliser in the older agricultural countries. Its use has been confined largely to the topdressing of vegetable crops. Sulphate of ammonia, on account of its abundant supply, has been much more generally used and is highly favoured by Western Australian farmers, particularly for potato, vegetable and orchard growing.

However, the situation is that no one source of nitrogen can be considered best for all soils under all conditions.

On the average on the more fertile soils, all ordinary types of nitrogenous fertilisers are equally efficient. Where the soil is inclined to be sour and low in lime, sulphate of ammonia induces soil deterioration and increases sourness. To maintain soil fertility adequate lime must be used in conjunction with sulphate of ammonia. Sulphate of ammonia is often less efficient on heavy clay soils owing to the absorption of the ammonia by the clay. On alkaline or heavily limed soil, ammonia may be lost by volatilisation. Nitrate of soda or nitrate of lime would be more effective nitrogenous fertilisers under these conditions.

Where the soils are light and readily leached by rain or irrigation water, as is the case in many parts of Western Australia, nitrate of soda must be used with judgment. In the wet winter months, on these soils it is likely to be ineffective if all applied at planting time, as it is liable to be washed out of the soil before the crop makes sufficient root growth to use it and take advantage of its value as a source of nitrogen.

Generally, nitrate of soda is at least as efficient as other forms of nitrogen for the growth of crops, but owing to its high solubility and ready availability it must be used with caution and in accordance with the soil and climatic conditions prevailing. Instances of poor results from nitrate of soda are almost invariably due *to its improper use* and not to the ineffectiveness of this form of nitrogen.

THE USE OF NITRATE OF SODA.

While growers may use their discretion and purchase the fertiliser of their fancy in peacetime, wartime conditions make it necessary to use whatever is available. The problem is to get the highest efficiency from all operations and to do this the farmers may have to modify their methods according to the properties of the fertiliser supplied. As supplies of nitrate of soda are now available for the State, maximum use may be made of it as it is impossible to get anything like normal quantities of sulphate of ammonia and blood and bone. The nitrate of soda has been obtained from Chile at considerable cost to the Commonwealth Government and is a very fine sample of the modern granulated fertiliser. In this condition it does not readily absorb moisture from the air and, in consequence, does not become sticky and nasty to handle. It readily mixes with superphosphate and the mixture maintains good physical conditions.

The following recommendations are made for the use of nitrate of soda in Western Australian agriculture:—

1. Use nitrate of soda in small amounts with superphosphate at planting for special annual crops sown in the low rainfall months of the year. The equivalent of from 1 to 2 cwts. of nitrate of soda per acre should be adequate at planting time.

2. Apply the remainder of the nitrate of soda available after the crop has effected a vigorous establishment and the rooting system has been developed to absorb the nitrate without danger of loss by leaching. Up to 4 cwts. of nitrate of soda per acre may be applied in one or more applications.

Split dressings of the readily available nitrogenous fertilisers are much more effective than all applied at one time—for instance, at planting. Two or more top-dressings with nitrate of soda up to the limit available are important in promoting growth and crispness in green vegetables such as cabbages, lettuce, silver beet, etc.

3. Nitrate of soda makes an excellent liquid manure when dissolved in water at the rate of one to two ounces per gallon. In this condition it is particularly effective for use with cabbages and similar vegetables a few weeks prior to cutting.

4. Do not apply nitrate of soda or mixtures containing nitrate of soda at planting in the wet months or under heavy sprinkler irrigation on sandy soils. As far as possible, fertiliser mixtures containing sulphate of ammonia for vegetable and potato crops will be made available for May to August planting. In the wet months use nitrate of soda for topdressing the crop after becoming well established.

5. For fruit trees, nitrate of soda should be applied either singly or mixed with other fertilisers about September. If applied too early there is danger of loss by leaching. Owing to limited supplies 3 cwts. of nitrate of soda per acre for citrus, 2 cwts. per acre for stone fruits and vine fruits and 1 cwt. per acre for apples and pears are allowed by the Fertiliser Rationing Office. These quantities, although considerably smaller than that advised by many horticulturists, will prove very efficient and valuable for these orchard crops.

Soil Moisture Conservation in Vineyards and Orchards.

ITS RELATION TO CULTIVATION, COVER CROPS, AND WEEDS.

G. H. BURVILL, L. J. H. TEAKLE, and L. T. JONES.

SUMMARY.

Experiments involving various cultural and mulching treatments have been carried out at Upper Swan during the spring and summer seasons of 1941-42 and 1942-43 on well drained alluvial soil similar to that in some of the Swan vineyards.

The results have confirmed the conclusions of investigators in many parts of the world that a loose dry soil mulch is, under these conditions, no more effective in conserving moisture than an unmulched surface provided the latter is free of weeds. Weeds are the major controllable factor in soil moisture losses during summer.

Heavy cover crops or green manure crops have been found to cause a big drain on soil moisture to a depth of six feet after mid-September.

Straw or similar mulching material spread on the soil surface did not give any practical advantage in moisture conservation.

It is suggested that for orchards and vineyards in Western Australia recent American recommendations might well be followed. This would involve the discing-in of green manure and cover crops in late August and early September leaving a rough trashy surface. A similar cultivation in October would control weeds. Soil erosion and deterioration of soil structure would be reduced to a minimum.

INTRODUCTION.

A widespread belief still exists among orchardists, farmers, and gardeners, that the periodic cultivation of surface soil to produce a fine loose mulch results in a saving of moisture which would otherwise be lost by evaporation. The soil mulch itself is credited with being able to prevent moisture losses, and the common explanation is that the so-called "capillary movement" of water from the subsoil to the surface is interrupted and hindered by a loose surface mulch.

During the past thirty years many investigations of soil moisture and soil management have failed to support this idea, and have even shown that too much cultivation can be damaging to the soil structure and reduce soil productivity. Then again, the costs of cultivation and the soil erosion menace have brought cultural practices into critical review during recent years, with the result that new methods, usually involving less frequent stirring of the soil, are commonly advised.

To quote Charles E. Kellogg* (1941) from his book, "The Soils that Support Us," page 222:—

"On the whole, modern farmers in the United States still plow and cultivate too much." And page 223—

"Rather than 'plow deep while sluggards sleep' one should plow well, at the proper time, and as little as possible, yet kill weeds, develop good seed beds, and make the soil receptive to rain water."

In a climate with winter rainfall and a dry, hot summer, as in the south-west of Western Australia, soil moisture conservation is vital for non-irrigated orchards and vineyards.

To obtain local data on mulches, cultural practices, and weeds in their relation to soil moisture, experiments have been conducted during the 1941-42 and 1942-43 summers at "Belhus," Messrs. Barrett-Lennard Bros.' property at Upper Swan. The Superintendent of Horticulture (Mr. H. R. Powell) suggested the desirability of local information, and the experiments have been carried out by the collaboration of officers of the Plant Nutrition and Horticultural Branches. Before passing to a consideration of these experiments a brief review of investigations on soil cultivation and mulching will be of interest.

REVIEW OF INVESTIGATIONS ON SOIL MULCHES AND CULTIVATION.

King at Wisconsin, and Hilgard and Loughridge in California, studied soil moisture conservation extensively towards the end of last century and considered that during dry periods soil moisture moves upwards to the surface by capillarity and there evaporates. They strongly recommended careful and thorough cultivation of the soil surface to maintain a loose dry soil mulch which would break the fine capillary tubes and so reduce the upward capillary movement. These recommendations became an important feature of dry land agriculture and the "dust mulch" idea became strongly ingrained into farming practice, especially for orchards and vineyards which are not irrigated and which make their growth during a relatively dry season. Since as early as 1910, however, many investigators, especially in America, have questioned the value of the soil mulch in moisture conservation, and, in 1915, Chilcott, Cole and Burr in the United States Department of Agriculture Bulletin, No. 268, summarised the results of a number of trials. They concluded that, provided there is no plant growth, the loss of water is practically the same from a mulched* surface as an unmulched one. Keen, of Rothamsted, in "The Physical Properties of the Soil" published in 1931, reviewed the evidence concerning the value of the mulch in soil moisture conservation and concluded that except under special conditions it is no more effective than a bare uncultivated surface. The special conditions referred to are when the free water table (as in a well) is within about six feet of the surface. Under these conditions

* Charles E. Kellogg is Principal Soil Scientist, Division of Soil Survey, Bureau of Plant Industry, United States Department of Agriculture.

* Unless stated to the contrary, a reference to a mulched surface implies a loose layer of soil on the surface produced by cultivating implements. The use of straw, sand, paper, gravel, etc., as mulches will be referred to specifically.

capillary movement can take place fairly rapidly and a loose soil mulch on the surface has been shown to be effective in reducing losses. In fact, a number of early experiments which brought the soil mulch into favour were done under laboratory conditions with the soil in tubes or cylinders standing in a reservoir of water. King carried out experiments under such conditions, and Shaw in California, in 1927, found that with a water table at four feet, the loss from two unmulched soil columns was more than 60 per cent. greater than that from columns of similar soil mulched two inches deep. The mulch was well stirred six times during the experiment after the initial mulching. An experiment under similar conditions showing the value of soil, manure, and grass mulches was reported by Throssell (1924) in this Journal.

A number of investigators in U.S.A., Canada, South Africa and Australia during the past 15 years have confirmed that, in moisture retention under field conditions with no shallow water table, only very slight advantage, if any, certainly nothing of practical importance, is achieved by creating a loose soil mulch. The important thing is that weed growth should be reduced to a minimum.

Early ideas with respect to soil mulching were based on the assumption that moisture could move through the soil by the process of capillarity just as oil moves through the wick in a lamp. It has been proved more recently, however, that capillary movement of moisture from wet to dry soils is very slow below field capacity—that is, below the maximum moisture content which a well drained soil can hold.

Straw, Paper, Sand and Gravel Mulches.

It has been shown at various times that mulches of straw, paper, sand, and gravel are effective in conserving soil moisture. Straw, leaves, manure, grass, etc., are often used around shrubs and the straw mulch is used in some of the orchards of Eastern U.S.A. for various benefits. An experiment carried out in tanks at Merredin Research Station in the past 12 years has shown clearly that much more moisture is conserved in heavy clay loam under a sand layer five inches thick, than under a loose soil mulch of the same heavy soil. This is because the rains pass more easily through the sand layer than through a layer of heavy soil of the same thickness, and also because the sand reduces the losses during dry periods. Some of the recent American work by Russel of Nebraska suggests that straw mulches are effective in periods when water is being periodically added to the soil—as under summer rainfall conditions—but no more effective than a soil mulch (or bare soil presumably) in long dry periods.

EXPERIMENTS AT "BELHUS"—UPPER SWAN.

The experimental site used at "Belhus" is located in a flat portion of a grazing paddock on alluvial soil similar to parts of the "Belhus" vineyard. It is well above the levels of Ellen's Brook and the Swan River, and no water table occurs within nine feet of the surface—it is probably much deeper. The chocolate loamy fine sand surface soil becomes red brown below two feet and continues so beyond six feet without any clay layers, so that it must be regarded as relatively light soil. When selected in August, 1941, the area carried a fine stand of New Zealand blue lupins and some wild radish estimated at 18 tons of green material per acre. This was similar to a very good vineyard or orchard green manure crop. A similar but variable growth of lupins, radish, and grass was on the plots in the 1942 winter.

Seven treatments involving cultural variations were decided on, and to repeat each five times, 35 plots each 10 feet square, were marked out in an area 70 x 50 feet. A random arrangement of the treatments was used within each of the five blocks of seven plots. The third week of August was chosen to commence the treatments as this is a common time for ploughing-under of green manure crops in the Swan vineyards. A second ploughing is often made in early October. The general treatments adopted in spring and summer seasons of 1941-42 and 1942-43, have been:—

A. Cover crop dug in August, second digging October. No cultivation thereafter during the summer.

B. Cover crop dug in August, second digging October, cultivation to about three inches at approximately monthly intervals to maintain loose soil mulch.

C. Cover crop allowed to grow to maturity—no cultivation.

D. Cover crop cut at ground level and removed in August and bare smooth surface maintained during spring and summer. No digging or cultivation.

E. Cover crop removed as in D but otherwise treated as A.

F. Cover crop cut in August and allowed to lie on surface as a mulch. No digging or cultivation.

G. Cover crop dug in August, second digging October, when a mulch of straw (1941) or green lupin plants (1942) was applied at approximately four tons of dry matter per acre.

In order to establish whether the soil mulch of treatment B possessed any virtues in moisture conservation, apart from the weed control achieved in producing the mulch, it was necessary to remove any weed growth from treatment A plots. This was not achieved in the period October-December, 1941, but subsequently and in 1942-43, weeds were carefully eliminated.

The moisture changes in the soil were determined by periodic samplings of all plots to a depth of six feet with a four inch post hole auger. Samples for moisture were taken in each case to represent the following layers: 0-6in., 6-12in., 12-24in., 24-36in., and 36-72in. Each hole was carefully filled and rammed after sampling and the sample holes were confined to an area five feet square in the centre of the 10 feet square plot. Five samplings were made from 20th August, 1941, to 19th March, 1942, and six samplings from 24th August, 1942, to 16th February, 1943.

RESULTS, 1941-42 SEASON.

The moisture data from the 1941-42 samplings are illustrated graphically in Figure 1 which also shows the rainfall at "Belvoir," about one mile away, during the same period. Actually a fall of 78 points recorded at "Belvoir" on 19th March has not been included because sampling of the plots was done on 18th and 20th March, and there was no indication that such a fall had occurred on the plots. Thunderstorms were common at this period and these are known to be associated with falls of rain over limited areas. The data are shown for the two layers

0-3 feet and 3-6 feet. To avoid confusion only four treatments, A, B, C, and D, are illustrated. E gave results substantially the same as A, while F and G were more closely related to B and D.

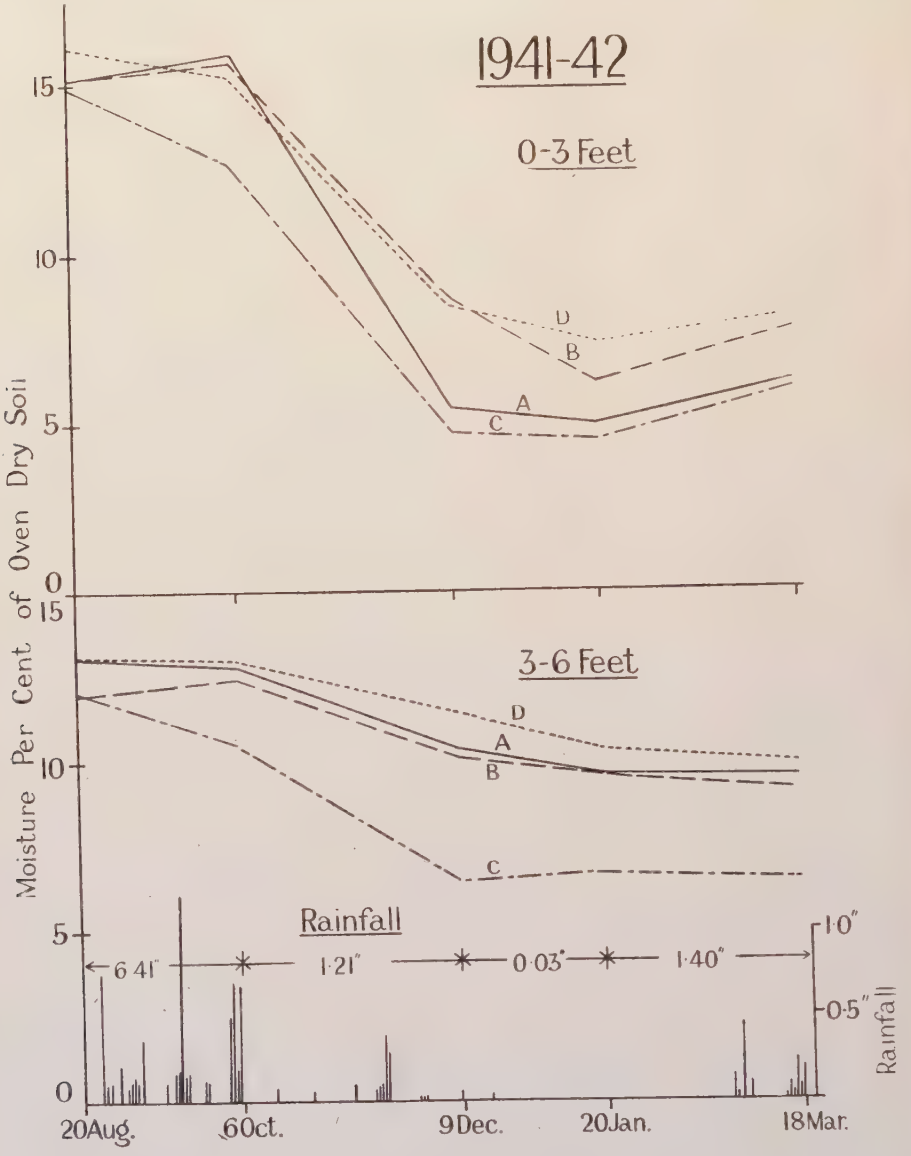


Fig. 1.

Soil moisture changes under various cultural and mulching treatments during spring and summer, 1941-42 :—

A.—Cover crop dug in 20th August. Second digging 6th October. No summer cultivations. Vigorous weed growth developed 6th October to 9th December, but afterwards controlled.

B.—Cover crop dug in 20th August. Second digging 6th October. Cultivated to 3 in. at intervals during summer (30th October, 10th December, 7th and 21st January.)

C.—Uncultivated. Lupin and radish cover crop grew to maturity.

D.—Bare smooth uncultivated surface. Cover crop removed 20th August, and weed growth chipped at intervals when B was cultivated.

Table 1 sets out the 1941-42 data in a different form. It shows the net gains or losses of moisture expressed as inches of rain during the various intervals between samplings. In this soil one per cent. of moisture to a depth of six feet is equivalent to one inch of rain.

TABLE 1.

EFFECT OF VARIOUS CULTURAL AND MULCHING TREATMENTS ON SOIL MOISTURE LOSSES DURING SPRING AND SUMMER, 1941-42.

(All figures expressed as inches of rain.)

Treatment.	Net Gain or Loss of Moisture to 6 feet deep.				Net Total Loss, 20-8-41 to 19-3-42.		
	20-8-41 to 6-10-41.	6-10-41 to 9-12-41.	9-12-41 to 20-1-42.	20-1-42 to 19-3-42.	0-6 ft.	0-3 ft.	3-6 ft.
A. Cover crop dug in 20th August. Second digging 6th October. No summer cultivations. Vigorous weed growth developed 6th October to 9th December, but afterwards controlled	+0·2	—6·5	—0·6	+0·7	6·2	4·35	1·85
B. Cover crop dug in 20th August. Second digging 6th October. Cultivated to 3 in. at intervals during summer (30th October, 10th December, 7th and 21st January)	+0·4	—4·7	—1·5	+0·6	5·2	3·75	1·45
C. Uncultivated. Lupin and radish cover crop grew to maturity	—2·0	—6·0	+0·1	+0·6	7·3	4·45	2·85
D. Bare smooth uncultivated surface. Cover crop removed 20th August and weed growth chipped at intervals when B was cultivated	—0·5	—4·2	—1·1	+0·2	5·6	3·95	1·65
E. Cover crop removed 20th August and plots dug as in treatments A and B. Weed growth developed and treated as on A	+1·1	—7·5	—0·7	+0·9	6·2	4·45	1·75
F. Cover crop cut and allowed to lie on surface. No cultivations but weeds chipped as on D	+0·8	5·9	—0·4	+0·2	5·3	3·85	1·45
G. Cover crop dug in 20th August. Second digging 6th October, and straw mulch (4 tons per acre) then applied. Weed growth controlled by plucking	+0·1	—5·0	—0·7	+0·3	5·3	3·75	1·55
Rainfall during same periods	inches. 6·41	inches. 1·21	inches. 0·03	inches. 1·40	inches. 9·05		

In considering both the graph and the table it should be remembered that small differences between the various treatments may be due to soil variability and to chance sampling errors. The detailed sampling showed that the soil was not as uniform as would have been expected, and at the first sampling of the plots on 20th August, 1941, before the treatments were commenced, the plots allocated at random to treatment D had a higher average moisture content to six feet than the other groups of plots.* This can be seen from Figure 1 which clearly shows the variations at the outset of the experiment.

In August and again in early October, except where the lupins and radish were still growing (C) the soil had as much water as it could hold—it was at field capacity—and it contained the equivalent of 14 inches of rain to six feet deep. Yet from 6th October to 9th December even the most effective moisture conserving treatments, B and D, showed a net loss of 4.7 and 4.2 inches of rain, respectively. The heavy weed growth of wild radish on A and E greatly increased this loss, while the maturing of the lupin cover crop on C caused a net

* Statistical analysis showed that D contained significantly more moisture than all other treatments at P = .05. Since prior to this date all plots were under cover crop the result must have been due to soil variations and chance sampling errors.

loss of eight inches from 20th August to 9th December. The intermediate losses of F and G were due to better weed control, especially after 30th October, than on A and E, but another factor accounting for greater net losses than on B and D may have been that the light November rains were insufficient to add much to the soil after wetting the surface mulch of straw (G) or the cover crop remains (F).

After 9th December the summer was very dry till the thunderstorms of late February and mid-March. During this dry period, some further loss of moisture occurred from the soils under treatments B and D. This was because these soils were still somewhat more moist than the others and evaporation continued until this surplus was removed. Under all other treatments the soil moisture had been previously reduced by 9th December to a minimum below which further loss by evaporation was practically eliminated. Because of thunderstorms in the week preceding the March sampling all treatments were moistened in the surface layers and a net gain is shown in Table 1. The graphs of Figure 1 show that the gain was in the upper layers while the 3-6 feet layer showed a further small loss, except for treatment C, which, owing to the action of the cover crop, had been previously reduced to the minimum attainable under natural conditions.

Real differences in the effects of the various treatments (except for C) were apparently confined to the first three feet and for this reason the data for 0-3 feet and 3-6 feet are shown on separate graphs in Figure 1. It will be seen later from Figure 2 that in the 1942-43 season the differences in effect were confined to the upper two feet except where the cover crop grew to maturity.

CONCLUSIONS FROM 1941-42 STUDIES.

The first season's work led to the following conclusions:—

1. Neither a loose soil mulch nor a straw mulch was appreciably more effective in moisture retention than a bare, smooth surface.
2. Growing weeds or cover crop greatly increased moisture losses, especially in the early summer period.
3. The heavy lupin cover crop when allowed to mature drew moisture from the soil to a depth of approximately six feet.
4. In spite of all moisture conservation methods applied, the moisture loss from the 3-6 feet layer of this soil was considerable. (See Table 1, last column.) Additional losses occurred where a cover crop was allowed to grow to maturity after the winter rains had ceased.

1942-43 SEASON.

The treatments used in the second season were very similar to those in 1941-42, but weeds were eliminated by attention at more frequent intervals. This was done on B by cultivation with a three-pronged garden cultivator, on D and F by chipping with a spade, and on A, E and G by pulling or careful cutting without disturbing the surface soil. As A and E gave parallel results lupins and wild radish which germinated after rain on 20th December were allowed to grow on the E plots and their effect on moisture losses assessed. Instead of straw, a mulch of green lupin plants was used on G. These were put on 14th October, and because of their stage of maturity, dried out and left rather woody stalks for the mulch. By contrast, the lupins and radish cut on F on 24th August were so green and sappy that they rotted away and left very little residue. This was also noted in the previous season.

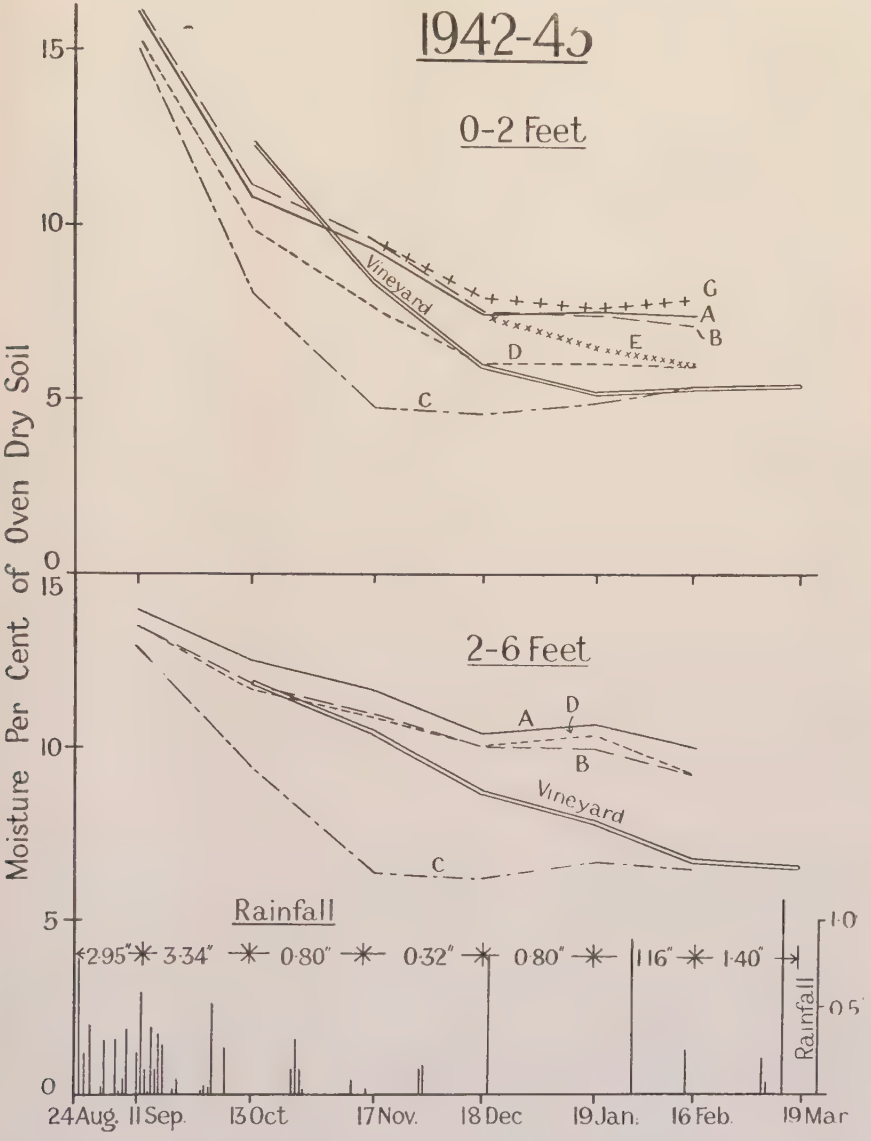


Fig. 2.

Soil moisture changes under various cultural and mulching treatments during spring and summer, 1942-43 :—

A.—Cover crop dug in 24th August. Dug again 13th October. No later cultivations, but weeds carefully removed when B was cultivated.

B.—Cover crop dug in 24th August. Dug again 13th October. Cultivated 4th and 17th November, 21st December, 1st and 20th January, and 17th February.

C.—Uncultivated. Cover crop of lupins and radish grew to maturity.

D.—Cover crop removed 24th August. Bare smooth uncultivated weed-free surface maintained.

E.—Cover crop removed and plots dug 24th August. Dug again 13th October. No later cultivations, but weeds removed till 20th December, *but not later.*

G.—Cover crop dug in 24th August. Dug again 13th October, when mulch of green lupin plants applied. Weeds under mulch periodically removed.

Vineyard.—Comparative data from vineyard on similar soil.

The moisture data and rainfall for this season are shown in Table 2 and on the graphs of Figure 2, where, to avoid confusion, only the data for A, B, C, D, and parts of E and G are illustrated. Because of the better weed control on the plots and the different character of the season's rain the different effects of the various treatments are, except for C, confined to the upper two feet of soil. The graphs of Figure 2 therefore give data for the layers 0-2 feet and 2-6 feet instead of 0-3 feet and 3-6 feet as in Figure 1. Table 2 is also presented in somewhat different form from Table 1 to better illustrate the data.

TABLE 2.

EFFECT OF VARIOUS CULTURAL AND MULCHING TREATMENTS ON SOIL MOISTURE LOSSES DURING SPRING AND SUMMER, 1942-43.

(All figures are expressed as inches of rain.)

Treatment.	Net loss of Moisture, 11-9-42 to 18-12-42.			Further net Change, 18-12-42 to 16-2-43.			Net Loss 11-9-42 to 17-2-43.	Moisture in Soil, 17-2-43.
	0-2 ft.	2-6 ft.	0-6 ft.	0-2 ft.	2-6 ft.	0-6 ft.	0-6 ft.	0-6 ft.
A. Cover crop dug in 24th August. Dug again 13th October. No later cultivations but weeds carefully removed when B was cultivated	2·87	2·36	5·23	*nil*	—0·27	—0·27	5·50	9·18
B. Cover crop dug in 24th August. Dug again 13th October. Cultivated 4th and 17th November, 21st December, 1st and 20th January, and 17th February	2·88	2·34	5·22	—0·10	—0·54	—0·64	5·86	8·55
C. Uncultivated. Cover crop of lupins and radish grew to maturity	3·43	4·46	7·89	+0·23	+0·16	+0·39	7·50	6·10
D. Cover crop removed 24th August. Bare smooth uncultivated weed-free surface maintained	3·07	2·34	5·41	—0·03	—0·54	—0·57	5·98	8·11
E. Cover crop removed and plots dug 24th August. Dug again 13th October. No later cultivations but weeds removed till 20th December, but not later	2·75	2·34	5·09	—0·43	—0·50	—0·93	6·02	8·43
F. Cover crop cut and allowed to lie on surface. No cultivations. but weeds chipped as on D	3·27	2·12	5·39	+0·23	—0·38	—0·15	5·54	8·11
G. Cover crop dug in 24th August. Dug again 13th October, when mulch of green lupin plants applied. Weeds under mulch periodically removed	2·73	2·34	5·07	*nil*	—0·44	—0·44	5·51	8·84
	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches
Rainfall during same period	....	....	4·46	....	....	1·96	6·42	....
	Period 14th October to 18th December, 1942.							
Data from four sites in similar soil among old Ohanez vines with roots going down at least 9 feet	2·13	2·07	4·20					
	Estimated Loss, 11th September to 18th December, 1942.							
	3·40	3·20	6·60	—0·20	—1·33	—1·53	8·13 (Estimated)	6·23

The spring and summer rainfall recorded at "Belvoir," about a mile from the experiment site, is set out hereunder:—

RAINFALL IN POINTS (100 POINTS = 1 INCH).

——	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total, 8 months.
1941-42 ...	375	339	218	105	8	*Nil*	18	200	1,263
1942-43 ...	627	357	165	11	112	90	26	173	1,561

The nature of each season is however, more clearly demonstrated by grouping the daily falls as follows:—

RAINFALL IN POINTS (100 POINTS = 1 INCH).

	Aug. 1 to 19.	Aug. 20 to Oct. 7.	Oct. 8 to Nov. 13.	Nov. 14 to Dec. 19.	Dec. 20 to Feb. 25.	Feb. 26 to Mar. 18.
1941–42	280	641	20	104	*Nil*	140
1942–43	323	757	77	35	196	140

In each case there were generous late winter and spring rains up to 7th October. Thereafter both seasons were relatively dry up to 19th December. After that date the 1941-42 season was very dry till thunderstorms brought rain in late February and March, but in 1942-43 almost two inches of rain fell in the period 20th December to 25th February, and there were further thunderstorm rains in March.

Reference to Table 2 and the graphs of Figure 2 shows that considerable moisture losses occurred again in 1942-43 under all the treatments tested. The loss where the lupin and wild radish cover crop was allowed to grow on to maturity (C) is very striking. Although 3.34 inches of rain fell between 11th September and 13th October, there was a big net loss of moisture, indicating the terrific drain imposed by a heavy annual crop at an advanced stage of growth. Relatively dry weather in late September and a week of dry weather prior to 13th October caused losses in other treatments besides C, and a comparison of Figures 1 and 2 suggests that by mid-October the soils in general contained less moisture than at the same date in 1941. The great value of spring rains to the vineyard and orchard is apparent.

By 17th November the cover crop on C was practically mature and the soil moisture to six feet had been reduced to about 5 per cent. in the first two feet and 6.4 per cent. in the 2-6 feet layer. There had been a net loss equivalent to eight inches of rain.

The elimination of plant growth from all other treatments resulted in a saving of 2½ inches of rain by 18th December, and this saving was practically the same for all these treatments. The bare smooth surface of D showed a slight disadvantage which was probably due to the packing and partial sealing of the surface soil under the impact of grazing stock and the winter and spring rains. The D plots were under treatment C the previous season and in May, 1942, carried a good growth of lupins, radish, and grass. They were heavily grazed by cattle in June and the lupins badly trampled and mostly killed. As a result in August these plots had the poorest growth of herbage, while other plots previously neglected by the stock had much better growth.

On the F plots the cover crop, which had been cut on 24th August and allowed to lie on the surface, rotted and dried up to leave only a very small residue. By 18th December these plots had become practically the same as D plots where the surface was deliberately maintained smooth and bare.

After the fourth sampling on 18th December thunderstorm rains of 80 and 90 points were recorded on 21st December and 31st January. These offset evaporation losses to a large extent, but the cultivations given to B plots did not

conserve more moisture than A and D on which, however, weed growth was suppressed. On the E plots, which on the 18th December were comparable with A, B, and G, the lupins and radish germinated by the 20th December rain, were allowed to grow. On various plots of the five under this treatment sparse to moderate growth developed and the plants had reached a height of 6 to 15 inches by 17th February. This treatment showed a net loss of 0.43 inches of rain from the upper two feet between 18th December and 17th February, compared with 0-0.10 inches from A, B, D, and G.

The 0-2 feet section of Figure 2 shows that G maintained the highest moisture content in this layer after 13th October, the date on which the mulch of green lupin plants was spread on these plots. A study of the detailed sampling data shows that this advantage is confined to the 0-12in. layer and was approximately one per cent. compared with A. Since the graphs for A and G are more or less parallel on and after 13th October the result may be due to chance soil variations. It must be remembered, too, that the 100 pounds of green lupin plants spread on each plot contained about 85 pounds of water, which is equivalent to one per cent. of moisture in a foot of soil. The drying of the lupin plants would no doubt slow up the losses from the soil. In any case the effect of the litter mulch on G, even if real, is equivalent to only 16 points of rain and was achieved only by rigid elimination of any weeds which germinated under the mulch. Under these conditions it must be concluded that such a mulch would have no practical benefits in saving moisture.

It was noted that at the end of the 1941-42 season the surface soil of G under the straw mulch was much more mellow and friable than the soil of say, treatments A and E, and was, of course, in striking contrast to the caked surface of C, D, and F. The straw or similar mulch absorbs the energy of the raindrops—it takes the "sting" out of them before they hit the soil surface. In America this is considered to be an important effect in reducing soil erosion.

Assuming that the cover crop on C removed from the soil all the available water to a depth of six feet in October and November, 1942, it is seen from Table 2 that, in this type of soil, to a depth of six feet moisture equivalent to six inches of rain is unavailable for plant growth.

MOISTURE CHANGES IN VINEYARD.

During the 1942-43 season moisture studies were also made at four sites among old Ohanez vines in the "Belhus" vineyard. The soil was very similar to that of the experiment site discussed above and samples were taken on similar dates. The results are included in Table 2 and Figure 2. The first sampling was not made till 13th October, so that the losses from 11th September to 13th October have been estimated assuming that on the 11th September the moisture level in the vineyard was the same as under treatment A.

The gradual withdrawal of moisture by the vines throughout the six feet sampled is clearly seen. This contrasts with the rapid withdrawal of moisture by the quick growing, annual cover crop of lupins and wild radish. The flattening of the graphs in the late summer suggests that practically all the available moisture was removed, although the equivalent of about six inches of rain still remained Borings showed that these vines had roots going at least nine feet, and in late summer, apart from thunderstorms, these deep layers must be drawn on for moisture by old established vines.

CONCLUSIONS FROM 1942-43 STUDIES.

The second season's work amplified that of 1941-42, and showed that under conditions as at "Belhus":—

1. Given complete weed control in each case, neither a loose soil mulch, constantly maintained by periodic cultivation, nor a mulch of plant material, applied at the rate of four tons of dry matter per acre, proved necessary to effect a maximum saving of soil moisture. An equal amount of soil moisture was retained over the summer months in plots which had only been twice dug, once in August and once in October, and the surface left in a rough condition.

2. The cover crop of New Zealand blue lupins and wild radish, when allowed to mature, drew moisture from the soil to a depth of about six feet and this loss occurred very largely from mid-September to mid-November. Under the grape vines the loss was more gradual and spread over a longer period.

3. Weed growth following on summer rains can cause substantial losses of moisture.

4. Plots which in neither season were dug over but had the cover crop cut (D and F) showed a greater net loss of moisture in spring and early summer than plots dug in August and October, apparently because the compact surface is less receptive to rain. However, plots dug over in spring showed no such effect even though several summer thunderstorms occurred.

Fig. 3.

Discing an annual cover crop in spring to leave much of the crop on the surface. This stops moisture losses through the growing crop and protects the soil from erosion and damage by late rains. A similar cultivation four to six weeks later will destroy weeds and further incorporate the cover crop with the surface soil.

[Reprinted from U.S.D.A. Farmer's Bulletin, No. 1917, 1942.]

PRACTICAL APPLICATIONS.

Since the loose soil mulch has, of itself, no virtue in soil moisture conservation, summer cultivation of orchards and vineyards will be of no benefit unless there are weeds to combat. Green manure and cover crops will cause very big moisture losses if they are not ploughed in by mid-September. In late August and early September these crops are, moreover, in excellent condition to rot in the soil when ploughed under, and the maximum benefit will follow.

The condition of the soil surface to receive and absorb rain is important, especially on sloping ground, if both runoff and soil erosion are to be reduced to a minimum. The impact of raindrops, especially in heavy showers, is an important factor in puddling the soil and sealing the surface. The pelting rain brings fine soil particles into suspension to be carried away as the water runs off the sealed surface. Considerable attention is now given in the United States of America to methods for keeping trash and crop residues on the surface to protect the soil and reduce erosion. For orchards, the dust mulch is right out of favour, and the discing of cover crops as shown in Figure 3 is recommended rather than a complete turning under. This guards against erosion losses while eliminating the cover crop as a competitor for moisture. Further cultivation later with a similar disc implement will control the majority of weeds and further incorporate the cover crop with the surface soil. A fine soil mulch need not be produced. Instead, quite a large proportion of the cover crop is left on the surface. In California this system of tillage is called "mulch tillage."

ACKNOWLEDGMENTS.

The authors are indebted to Mr. St. A. Barrett-Lennard for making available the experiment site at "Belhus," and materials to fence it; also for his keen interest in the results of the work. Mr. W. Jamieson and Mr. S. E. Bennett of the Horticultural Branch, also Messrs. F. V. Bridgman and G. J. Dwyer, rendered valuable assistance at various times with the digging and sampling of the plots.

Pedigree Seed.

It is anticipated that supplies of pedigree seed wheat, oats and barley will be available for distribution from the forthcoming harvest at the Research Stations.

Conditions of purchase will be the same as for last season, and farmers will be able to obtain their supplies either on a cash basis or in exchange for their own f.a.q. wheat delivered at the siding.

The rates of exchange and cash prices for wheat, oats and barley are:—

Exchange:

4½ bushels f.a.q. wheat* for 3 bushels pedigree seed wheat or barley.

3¾ bushels f.a.q. wheat* for 3 bushels pedigree seed oats.

* Or its equivalent in docked wheat.

Cash:

Wheat Belt Areas—

Wheat and barley—18s. per bag of 3 bushels.
Oats—13s. 6d. per bag of 3 bushels.

South-West Areas—

Wheat and barley—18s. per bag of 3 bushels.
Oats—15s. per bag of 3 bushels.

All of the above transactions are inclusive of rail freight to applicant's siding.

At present it is anticipated that seed of the following varieties will be available:—

Wheat: Late maturing—Febweb, Kondut.*
Mid-season maturing—Baroota Wonder, Bencubbin, Ford, Nabawa.
Early maturing—Gluyas Early, Koorda*, Merredin.
Very early maturing—Bungulla.
Premium varieties—Comeback, Pusa IV.

Oats: Late maturing—Algerian.
Mid-season maturing—Dale*, Guyra.
Early maturing—Ballidu*, Mulga.
Very early maturing—Wongan.

Barley: 2-row—Pryor.
6-row—Atlas.

Varieties marked with an asterisk are new productions of the Department, and were first made available for distribution for the current season's planting.

It is not intended that farmers should obtain their full supplies of seed from the Department but that by periodically buying small quantities of pedigree seed and growing their own stud seed plots, the quality of their seed will be maintained at a high level to their own benefit.

Also owing to only limited quantities of some varieties being available it is usually necessary to limit the number of bags of any one variety, and also may be necessary to limit the number of varieties per applicant. In view of this it will be of considerable assistance if applicants indicate their order of preference when making application.

When applying for seed, applicants should clearly state their full name and postal address, and also the *siding* to which they desire the seed railed.

Attention is drawn to the fact that though applicants are advised that their application has been recorded, no definite reservation can be made until after the receipt of the necessary warrant or cash remittance.

Prompt attention should therefore be given to all correspondence, particularly with regard to forwarding the warrant or cash remittance after receipt of the statement of account. The sheet of instructions accompanying these statements should be read carefully. Attention to these details will avoid disappointment.

All applications should be made *direct* to the Department of Agriculture, Perth, at an early date.

The Copper, Manganese, and Zinc Content of Subterranean Clover and Oats in Western Australia.

L. J. H. TEAKLE* and A. G. TURTON.†

SUMMARY.

A survey of the copper, manganese, and zinc content of subterranean clover, oats, wheat and barley representing soils over a considerable portion of the agricultural areas of the State is reported. These results may be considered in conjunction with experiments with plants and animals already reported in this and other Australian journals.

The results show that copper deficiency is general in certain districts of the State. Of these, Gingin, Dandaragan, South Busselton and the south coastal districts appear most severely affected.

Instances of copper deficiency are widely scattered over the whole of the agricultural areas investigated but are confined to certain soil types.

The better class soils, including loams and clay loams, are almost invariably well supplied with copper. Sandy loam soils are generally at least moderately well supplied with copper. In the majority of cases, copper deficiency is associated with sandy and gravelly soil types, but only certain classes of these soils appear to be low in available copper.

While there is experimental evidence of the occurrence of manganese deficiency with respect to a number of crops, this disorder does not appear to be general in Western Australia.

The analyses of subterranean clover and cereals indicate that zinc deficiency may occur on a number of light soil types in Western Australia. Further information regarding zinc deficiency will be necessary before any definite statement can be made.

The copper, manganese, and zinc deficiencies may be controlled by use of these substances in the fertiliser mixtures.

I. INTRODUCTION.

The correction of mineral deficiency of soils has played a large part in the establishment of agriculture in Western Australia. First and foremost is the need for generous fertilisation with phosphates. Nitrogen and potash are required under some circumstances by certain crops. Of recent years attention has been focussed on the micro-element deficiencies. Results from the use of these substances have been spectacular in many districts with certain soil types.

Cobalt.

Underwood and Filmer (1935, 1936) discovered that cobalt deficiency was the cause of *enzootic marasmus,* a wasting disease of cattle and sheep at Denmark. In Western Australia, administration of licks or drenches containing cobalt are effective controls and have become standard practice where the disease occurs. These treatments, together with the use of cobalt containing fertilisers, have been adopted as control measures in a number of parts of the world, notably New Zealand and Scotland.

* Plant Nutrition Officer, Department of Agriculture.

† Chemist, Government Chemical Laboratory.

Cobalt deficiency is not known to affect plants, although the cobalt content of plant matter varies considerably according to the soil conditions.

Copper.

Much has been written on copper deficiency of crops in Western Australia. Wickens (1924) recognised exanthema of deciduous fruit trees and recommended the use of bluestone for its control. Pittman (1935) associated a mottle leaf condition of fig trees with copper deficiency, and some success in its cure has resulted from the application of bluestone to the soil. Dunne (1938) found copper treatment effective in the prevention of wither-tip of apples in Western Australia. Bennetts and Chapman (1937) established that copper deficiency was the primary factor in *enzootic ataxia*, a rickety type of disorder of lambs and sheep at Gingin, Dandaragan and Pardelup. This work has been extended to other districts and the results are discussed by Bennetts and Beck (1942). Another early symptom of copper deficiency in sheep is "stringy" wool. Bennetts (1942) has described this disorder and its distribution in Western Australia. Bennetts, Harley, and Evans (1942 (a) and (b)) have shown that "Falling Disease" of cattle in the Margaret River area is the fatal termination of acute copper deficiency. Further evidence of the unsatisfactory growth of crops, pastures and grape vines due to copper deficiency has been presented by the writers and their colleagues in many papers in this Journal.

In view of the occurrence of copper deficiency in many districts in Western Australia, particularly in agricultural industries of importance under war time needs, officers of the Department of Agriculture and the Government Chemical Laboratory have collaborated in a joint survey, the details of which are reported in this paper.

The prevention and cure of copper deficiency in crops is simple and cheap. Fertilisers containing copper as bluestone, copper ore, roaster residues and other substances in which the copper is more or less soluble, supply adequate quantities and result in the growth of normal crops.

Manganese.

Manganese deficiency of cereals was recognised by Carne (1927) at Dwarda and since then the disorder, often known as the "Grey Speck Disease" on account of the descriptive name given it by workers in Germany and Holland, has been identified on many areas in the Great Southern. Soil types most commonly affected are those associated with mallet hills. Teakle and Wild (1940) have described soil conditions associated with manganese deficiency of cereals. Manganese deficiency of certain vegetable crops occurs on calcareous soils, often swampy in nature, in the Albany and Perth metropolitan districts. Fruit trees, particularly apples, give evidence of manganese deficiency on gravelly soils in a number of parts of this State (Dunne, private communication).

Control is effected by the use of fertilisers containing manganese, generally in the form of crude manganese sulphate.

Zinc.

The results of the investigation of unthrifty growth of pines at Myalup (west of Harvey), Ludlow (near Busselton), at Margaret River and at Pardelup, have led to the diagnosis of zinc deficiency. Kessell and Stoate (1938) have described the spectacular responses of pines affected with this disorder to treatment with zinc and show that zinc sulphate sprays are very effective and cheap in promoting regeneration. Agricultural crops, however, have shown little evidence of zinc

deficiency in Western Australia. A chlorosis or mottle leaf of citrus has been cured by the administration of zinc as a spray or soil dressing, and recently, experiments with cereals at Dongara (Teakle, 1942) and with subterranean clover at Many Peaks (east of Albany) have shown that zinc and copper in combination are necessary for optimum results under certain soil conditions. There is also some evidence of response of subterranean clover to zinc-containing fertilisers at Mungedar, Dandaragan.

II. COPPER, MANGANESE, AND ZINC SURVEY OF CROPS.

The recognition of the occurrence of deficiencies of copper, manganese and zinc affecting crop growth as well as animal health in Western Australia has led to a considerable number of investigations. The present investigation was designed to obtain evidence regarding the location and possible extent of deficient areas.

A survey of the copper content of Western Australian pastures by Beck (1941) indicated the probable widespread occurrence of soil types subnormal in available copper status. Areas in which experiments with crops have shown response to copper-containing fertilisers have been mentioned by Teakle (1942). Figure 1 illustrates the pertinent information given in the sketch map incorporated in the 1942 paper showing centres at which copper deficiency has been demonstrated.

This work has been extended by a survey of the copper, manganese, and zinc content of subterranean clover, oats, and in some cases, wheat and barley, grown on a wide variety of soils representing a considerable portion of the agricultural areas of Western Australia. The sampling was carried out mainly in 1941 and 1942, but the records presented include a few samples from earlier work.

The first problem in this survey was the selection of suitable plants which from their chemical composition, would be useful indicators of the copper, manganese, and zinc status of the soil. Oats were selected as a probable indicator for the wheatbelt and subterranean clover for the wetter area. In view of the results of the investigations on the zinc composition of plants in Victoria, the oats were sampled in the early growth stage, generally from six to nine weeks after planting, and when the crop was six to eight inches tall. For convenience, subterranean clover was sampled in the middle of the flowering period, generally in October and early November, dependent on the earliness or lateness of the district. In some cases where wheat or barley was being used for experiments with copper-containing fertilisers, these crops were used as indicators instead of oats.

Oats appear satisfactory as a general indicator of copper deficient areas. Wheat and barley seem to behave similarly. Information presented below indicates that the copper content of the oats is low in deficient areas, and is much higher where availability of the copper is known to be satisfactory. While the evidence is scanty and not conclusive, it seems likely that oats will be useful as an indicator of the zinc status of soils. Results for manganese are quite indefinite.

The subterranean clover has proved to be a very valuable indicator plant. In this work, only the leaves, including the full petiole and leaflets, were taken in order to standardise sampling technique. The analysis of the leaves shows a remarkably good correlation between copper content and the known condition of the country with respect to copper. There is also good evidence that the zinc content of the leaves is a reliable indication of the zinc status. As with oats, the evidence with respect to manganese is indefinite.

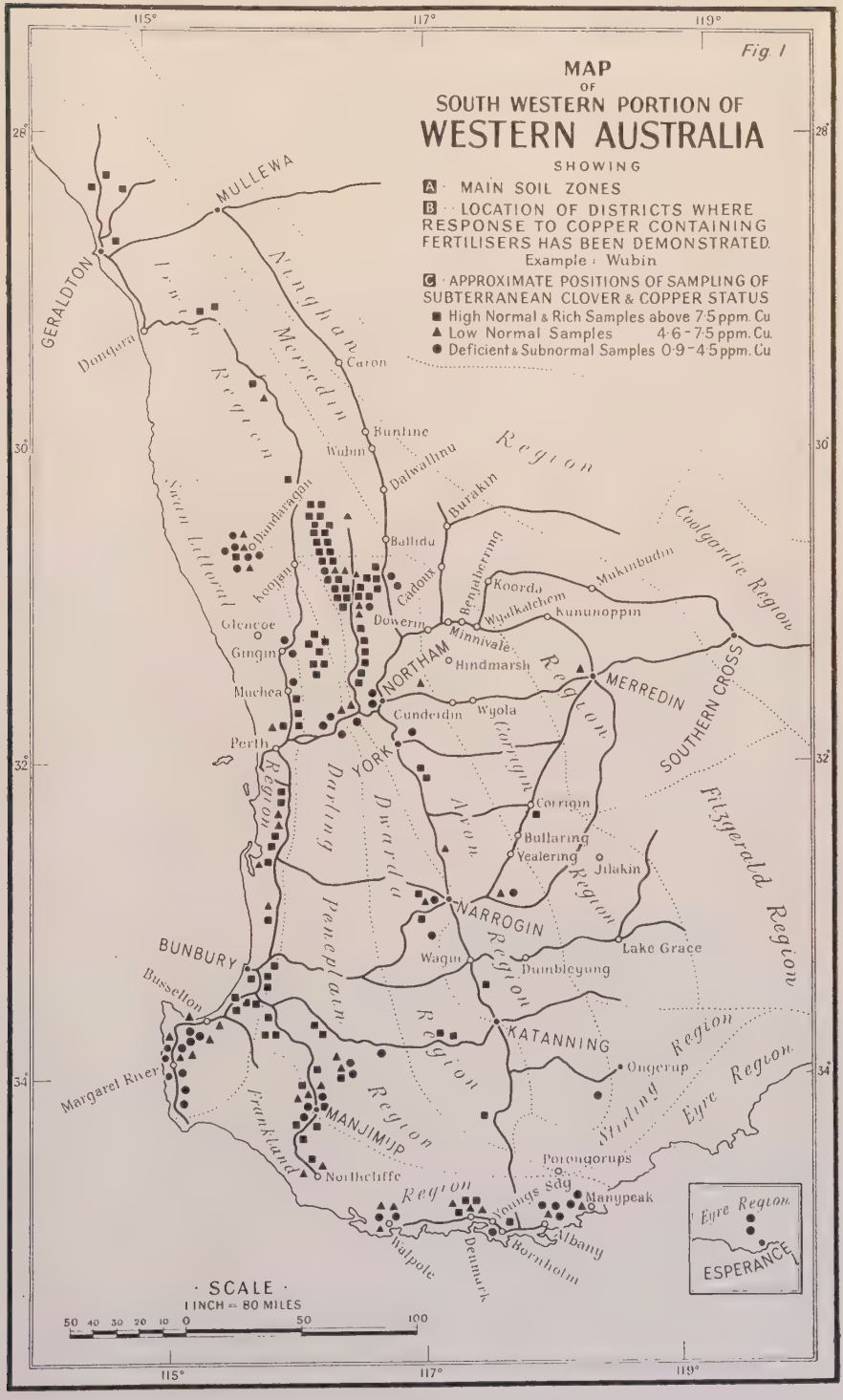


Fig. 1
MAP
OF
SOUTH WESTERN PORTION OF
WESTERN AUSTRALIA
SHOWING
A · MAIN SOIL ZONES
B · LOCATION OF DISTRICTS WHERE RESPONSE TO COPPER CONTAINING FERTILISERS HAS BEEN DEMONSTRATED.
Example : Wubin
C · APPROXIMATE POSITIONS OF SAMPLING OF SUBTERRANEAN CLOVER & COPPER STATUS
■ High Normal & Rich Samples above 7·5 ppm. Cu
▲ Low Normal Samples 4·6 - 7·5 ppm. Cu.
● Deficient & Subnormal Samples 0·9 - 4·5 ppm. Cu
115°
117°
119°
28°
30°
32°
34°
MULLEWA
GERALDTON
Dongara
Irwin
Arrowsmith
Moresby
Region
Caron
Buntine
Wubin
Dalwallinu
Region
Burakin
Coolgardie Region
Bandaragan
Sand plain
Coastal
Koojan
Ballidu
Cadoux
Koorda
Bencubbering
Mukinbudin
Wyalkatchem
Kununoppin
Glencoe
Gingin
Dowerin
Minnivale
Hindmarsh
NORTHAM
Region
MERREDIN
SOUTHERN CROSS
Muchea
Cunderdin
Wyola
Perth
YORK
Darling
Region
Avon
Corrigin
Region
Fitzgerald Region
Corrigin
Bullaring
Yealering
Jilakin
Darling
Range
Region
Dwarda
Avon
Region
NARROGIN
Wagin
Dumbleyung
Lake Grace
BUNBURY
Busselton
Margaret River
Preston
Region
KATANNING
Ongerup
Stirling
Region
Eyre Region
Frankland
Region
MANJIMUP
Northcliffe
Pemberton
Region
Youngs Siding
Manypeak
Albany
Walpole
Denmark
Hornholm
Eyre Region
ESPERANCE
· SCALE ·
1 INCH = 80 MILES
50 40 30 20 10 0 50 100

Subterranean clover is also of particular value in indicating the response to copper-containing fertilisers. Not only is the growth greatly improved on copper deficient soils, but the copper content of the leaves is greatly increased, and areas of subterranean clover pasture receiving copper fertilisers on copper deficient areas appear normal in copper content. The zinc content of subterranean clover leaves appears to be raised substantially by fertilisers containing zinc. On the other hand, oats were very disappointing from this viewpoint. While very great increase in growth occurred from the use of copper-containing fertilisers on copper deficient soils, the copper content of the oats was improved only to a very minor degree by the treatment.

In the course of this survey 202 samples of subterranean clover leaves and 56 samples of oats (including a number of wheat and barley samples) have been examined. Details of the analyses of the subterranean clover leaves are given in Appendix A, and of the oats, wheat, and barley in Appendix B.

In Appendix A the samples have been segregated according to the soil regions of the State as described by Teakle (1937). Briefly, the chief features of the regions from which samples have been obtained are as follows:—

1. *The Swan Littoral Region.*

The Swan Littoral Region extends, as a narrow strip of country lying between the coast and the Darling Range, from Dandaragan in the north to Karridale in the south. The soils vary widely and include coastal sands, high quality alluvial soils and a variety of gravelly types. The chief timbers are jarrah, marri, and tuart. Three areas notable for copper deficiency of crops occur in this region. These are the Gingin and Dandaragan districts, where the soils are formed on Cretaceous rocks, and the South Busselton area, where the granites appear to be very deficient in minerals supplying copper.

2. *The Darling Peneplain Region.*

This region includes the plateau country of the Darling Ranges, extending from Wannamal in the north to Mt. Barker in the south. The soils are chiefly gravelly types, except where rivers have removed the laterite and exposed the country rocks as at Bridgetown, Balingup, etc. The timbers are chiefly jarrah and marri.

3. *The Frankland Region.*

The Frankland Region extends along the south coast from Hamelin Bay to Many Peaks, east of Albany. The chief timbers include karri, jarrah, and marri, and, while many of the soils resemble those of the Darling peneplain region, there are considerable areas of poorly drained soils, such as the kangaroo grass, bottlebrush, and blackboy flats.

4. *The Dwarda Region.*

The Dwarda Region extends as a narrow strip from Koojan in the north to Cranbrook in the south, and includes a range of sandy and gravelly soils associated with the wandoo (white gum) belt of the State.

5. *The Irwin Region.*

The Irwin Region extends from Ajana to Walebing and is characterised by the jam and York gum soils of the northern agricultural areas. It includes a large proportion of sandy and gravelly soils.

6. *The Avon Region.*

The Avon Region represents an extension of the Irwin Region and stretches from Walebing to Borden. In the southern portions, however, the soils are more gravelly and appear more highly leached. Besides jam and York gum, other timbers such as wandoo, morrel, and salmon gum are important in some districts.

7. *The Eyre Region.*

Principally sandplain country along the south coast from Many Peaks to Israelite Bay, east of Esperance.

8. *The Corrigin and Merredin Regions.*

Salmon gum, gimlet, morrel, and sandplain country, representative of the wheatbelt.

The analyses for copper, manganese, and zinc have been examined by means of distribution tables which have brought to light information which is deemed to be of fundamental importance. The results of this examination are given in Tables 1, 2, 3, 4, 5, and 6. In these distribution tables uniform intervals have not been used as a difference of, say, 1 p.p.m. is much more important in the lower ranges than in the higher ones. It was found that the use of intervals increasing successively by the factor 1.2 gave a reasonable number of ranges and placed the desired emphasis on small differences in the lower ranges.

As a graphic representation of the analytical results for subterranean clover, Figure 1 has been constructed to indicate the copper contents of samples obtained from various parts of the State.

For this purpose the samples have been segregated into three groups:—

(a) Deficient and subnormal—samples containing 0.9 to 4.5 p.p.m. of copper, indicated by the dots.

(b) Low normal—samples containing 4.6 to 7.5 p.p.m. of copper, indicated by the triangles.

(c) High normal and rich—samples containing more than 7.5 p.p.m. of copper, indicated by the squares.

Where too many samples had been obtained from one district to show each on the map without undue crowding—as at South Busselton—the position is represented by plotting half of the figures from each group.

The centres shown in small print on the map are districts in which copper deficiency of certain soils has been demonstrated by experiments. To indicate the main centres of the State, a few other towns at which no experimental work has given positive results have been plotted in block letters.

III. DISCUSSION.

(*a*) *Copper.*

The data are most extensive and particularly interesting with respect to copper, and a number of valuable points are brought out by the distribution tables 1 and 2.

(i) *Range in Copper Content.*—Both subterranean clover and oats show an extraordinary and similar range in copper content. For oats, the range is 0.9 to 20 p.p.m. and for subterranean clover 0.9 to 31.9 p.p.m. of copper in the dry material. This appears to be a very wide range in composition with respect to an element of vital importance in the crop growth. It may be interpreted to mean that, after meeting the relatively small fundamental needs of the plant, copper is accumulated and, where the soil conditions are suitable, luxury levels may be attained.

(ii) Consideration of the copper contents of subterranean clover and oats from areas where copper deficiency was known to exist shows a very close correlation between the copper content of the foliage and copper deficiency. For both subterranean clover and oats grown on copper deficient areas, over half of the samples contained less than 3 p.p.m. of copper.

It seems desirable that some explanation should be made with respect to the considerable number of samples of subterranean clover leaves from copper deficient farms in the South Busselton district which fall in the normal ranges—chiefly 4.7 to 8.4 p.p.m. of copper (Table 1). It is thought that many of these results are anomalous and not indicative of the fundamental copper status of the farms in question. Five of the 10 samples in the 4.7 to 8.4 ranges are from farms in which samples obtained previously from adjacent portions showed about 2 p.p.m. of copper. The soil conditions appeared similar and the subterranean clover had uniformly disappeared some years before due, perhaps to copper deficiency. The supposedly anomalous samples were obtained from control plots (receiving no copper as fertiliser) in experiments laid down in 1941 and designed to test the value of copper in various forms for the regeneration of a subterranean clover pasture, when resown with a generous quantity of seed. It seems possible that the intensive grazing of the experimental areas in the winter months has caused the effect of the copper fertiliser to be spread to the control plots and so raised the copper content of the newly established pastures.

The high copper samples from Dandaragan were taken from small patches at most a few square chains in extent, where subterranean clover had persisted for many years although it had failed generally in the rest of the paddocks. The patches were areas where seepage occurred and undoubtedly the soil is more generously supplied with available copper than is usual for the district. This information is of considerable interest in indicating the copper content of subterranean clover which has persisted for many years in an area where this species—prior to the introduction of copper fertilisers—has generally proved a failure.

(iii) Study of the distribution tables for copper indicate that the copper analyses group themselves into a number of subdivisions. Mention has already been made of the subdivision in which the samples contain from 1 to 3 p.p.m. of copper and which is characteristic of the most notable copper deficient areas. The rest of the samples ranging in copper content from 3 to 30 p.p.m. appear to include two main subdivisions. One from 3 to 7½ p.p.m. and the other above 7½ p.p.m. This segregation is not very apparent from the distribution table but the break between them is emphasised by further segregation of the samples in the 6.5 to 8.4 p.p.m range into smaller ranges as follows:—

Range.	6·5–6·9.	7·0–7·4.	7·5–7·9.	8·0–8·4.	Total.
No. of Samples	7	6	1	7	21

The paucity of samples in the 7.5 to 7.9 p.p.m. range supports this segregation. There seems every likelihood that these three subdivisions represent a fundamental characteristic of the Western Australian soil based on the nature of the underlying rocks which appear to fall into three main types according to copper status as follows:—

(a) Rocks very low in minerals supplying copper as occur in the South Busselton, Gingin and Dandaragan districts.

(b) Rocks generally of the granitic type moderately supplied with copper-supplying minerals.

(c) Rocks such as the better types of granites, dolerites, and basic schists which are well supplied with minerals from which are released adequate quantities of copper.

This grouping is more clearly indicated by the distribution table (Table 1) for subterranean clover than for oats (Table 2). It is possible that the oats would have shown a similar distribution had sufficient samples been taken and had the sampling been extended to cover all types of country with the object of obtaining a cross-section of the agricultural areas. In this work the oats were obtained largely from the lighter soil types.

From the nutritional point of view these subdivisions have been further divided into a number of groups which are proposed as a basis for judging the copper status of the soils with respect to plant nutrition. Using subterranean clover as the basis the proposed groups are:—

(1) Deficient—up to 3 p.p.m. of copper. In this group stalling of subterranean clover due to copper deficiency is likely and the stock will be unable to get adequate supplies of copper from the feed to maintain health.

(2) Subnormal—3.0 to 4.5 p.p.m. of copper. Subterranean clover may persist, if not thrive, but the copper intake for stock will be below that suggested as the lower limit by Beck (1941).

(3) Low normal—4.6 to 7.5 p.p.m. of copper. These represent soils formed on the more acidic types of granite rocks which cover a very considerable area of the State. Copper status is probably adequate for the normal growth of subterranean clover. Where the copper content is generally below 6 p.p.m. of copper the stock may not receive optimum copper requirements (Underwood private communication).

(4) High normal—7.5 to 15 p.p.m. of copper. Subterranean clover samples falling in this range represent growth on the stronger soils generally and where the parent rocks are more basic in character.

(5) Rich—above 15 p.p.m. of copper. Subterranean clover apparently has the capacity to absorb copper well beyond that actually needed for vigorous growth. Analyses above 15 p.p.m. are deemed to represent a luxury concentration of copper. It is possible that such high quantities of copper in the feed may not be to the advantage of certain classes of stock.

(iv) *Copper content of subterranean clover in relation to soil texture.*—From the distribution table (Table 1) evidence is presented regarding the analyses of subterranean clover on soils of different textures. This table indicates that it is very unusual for samples from loams to contain less than 7.5 p.p.m. of copper.

Practically all of the samples fall in the high normal and rich groups. The sandy loam soils exhibit a wider spread in the copper content of the subterranean clover. Generally, however, the samples from these soils show at least normal copper content. It is the sandy and gravelly soils which have produced the majority of the deficient and subnormal samples which contain less than 4.6 p.p.m. of copper. However, 61 per cent. of the samples on these soils contained at least normal amounts of copper. This lack of correlation between soil texture and copper content is disconcerting to the soil surveyor as it means that the wide range of soil types in Western Australia which fall in the sandy and gravelly categories cannot be judged for copper status on ordinary physical characteristics. It means that it will be necessary to study some other fundamental property and it is hoped that a determination of the heavy mineral content of these soils will give the key to the problem. By "heavy" mineral is meant a mineral heavier than quartz, such as hornblende, augite or epidote. These minerals commonly contain chemical elements of value in plant and animal nutrition.

Information regarding the analysis of clover from overseas sources is not very extensive. A selection of these has been summarised by Beeson (1941). The average of some 48 samples of red clover and alsike clover was 10 p.p.m. of copper with a range of 5 to 20 p.p.m. If we assume that subterranean clover leaves resemble red clover and alsike clover in copper content, this information indicates that the deficient and subnormal groups do not represent normal conditions in other countries. Western Australia is apparently unique in having such a wide variety of soils on which the clover exhibits copper concentration below 5 p.p.m.

(*b*) *Manganese.*

The data for manganese expressed in Tables 3 and 4 are inconclusive. It is known that manganese deficiency of cereals and fruit trees occurs in Western Australia, but no cases of clover being affected are known.

None of the samples obtained in this survey has been from areas on which manganese deficiency is known to exist. The range for analyses shown in Tables 3 and 4 is not suggestive of exceptionally low manganese status either for the oats or the clover. Unlike that for copper, it compares closely with the range given by Beeson (1941) for 86 samples of clover, including hop, alsike, crimson and red varieties which was 18.5 to 875 p.p.m. with an average of 145 p.p.m. of manganese. As with copper, many plants have the capacity to absorb large quantities of manganese when the conditions are conducive and it is thought that the high average given by Beeson reflects the effect of a considerable number of samples containing a luxury quantity of manganese.

(*c*) *Zinc.*

While a considerable amount of work with zinc deficiency has been carried out in Victoria, insufficient results have yet been published to establish the zinc content of deficient plants. In discussion with the Victorian workers it has been learned that, for cereals at least, it is necessary to obtain samples in the early growing period to get satisfactory results indicative of the zinc status of the soil. As the plant matures the differences observed in the early growth stages are eliminated and interpretation of analyses becomes difficult. In view of the recommendations of the Victorian workers an endeavour was made to obtain all samples of oats, wheat, or barley used in this investigation within six to eight weeks after planting. With respect to subterranean clover, as mentioned above, the samples were taken at the height of the flowering period. It was hoped that, as for copper, this growth stage would be suitable for work with zinc.

While it is not possible to lay down standards, it seems likely that the cereals at six to eight weeks from planting or the subterranean clover in the mid-flowering period should contain at least 20 p.p.m. of zinc to be regarded as normal. Analyses of subterranean clover from two areas where zinc deficiency has been established, suggests that the deficiency is more or less acute when the analyses are as low as 10 to 15 p.p.m. of zinc.

From the distribution tables (Tables 5 and 6) it seems that 13 per cent. of the samples of subterranean clover could be regarded as deficient and another 9 per cent. as subnormal, if not deficient. For oats, approximately 40 per cent. of the samples can be regarded either as deficient or subnormal. This conclusion is supported by the evidence presented by Beeson (1941). Forty-eight samples of alsike and red clover gave an average of 45 p.p.m. of zinc with a range of 24 to 70 p.p.m. Beeson's evidence with respect to cereals cannot be used as a basis for judging the results reported in this paper.

(d) Foliar Diagnosis and Soil Mineralogy.

The visual examination of soils having proved very uncertain as a means of detecting deficiencies it is necessary to resort to botanical, chemical, and mineralogical methods. Where the deficiencies are highly acute it is often possible to diagnose the trouble as a result of certain symptoms. However, many symptoms of nutritional disorders are not very definite and, generally, botanical characteristics are of limited value in the diagnosis of mineral deficiencies when not acute. Chemical examination of the foliage of oats and subterranean clover, or foliar diagnosis as it is commonly termed, has proved very satisfactory with respect to copper, and is promising for zinc. But the method is slow. It is necessary to wait for the crop to grow and it is possible that, with virgin country, the early analyses may be normal with respect to soils of low status until the small native resources of the soil are depleted and the deficiency manifests itself.

Of recent years the possibility of detection of the nutritional status of the soil from the actual mineral grains composing it has been investigated. There is evidence, at least with respect to copper and cobalt deficiency, that soils low in certain types of mineral grains are open to suspicion. As the mineralogical examination of the soil is quick and relatively simple in the hands of the experienced mineralogist, there is a prospect of this method being of considerable diagnostic value in the future judgment of soil fertility and in the recommendation of suitable fertiliser treatments to meet the requirements of the crop.

(e) Correction of Mineral Deficiencies of Soils.

The mineral deficiencies of soils under agricultural conditions are best corrected by means of appropriate fertilisers. Superphosphate has been adopted generally in Western Australia as a means of correcting the primary deficiency in phosphate. At little added expense, elements such as copper, manganese, and zinc can be added to the superphosphate and applied where evidence of deficiency of these elements has been obtained. Applications of copper as low as 5 lbs. of bluestone per acre have been known to remain active in the soil for several years, so that the expense involved in the use of copper as a fertiliser in Western Australia is very small.

Where stock deficiencies have become apparent, and it is not convenient or possible to use appropriate fertilisers, licks and drenches may be used as suggested by Bennetts and his colleagues in the veterinary services.

TABLE I

COPPER CONTENT OF SUBTERRANEAN CLOVER LEAVES IN WESTERN AUSTRALIA ON LAND NOT FERTILISED WITH COPPER.

Distribution Table showing Percentage of Samples in each Range.

(A) For all samples. (B) On all farms on which copper deficiency has been demonstrated by experiments. (C) By soil regions. (D) By soil textures.

Samples.	Range of Copper Contents—p.p.m. Dry Material.										No. of Samples.
	Up to 2·0.	2·1–3·2.	3·3–4·6.	4·7–6·4.	6·5–8·4.	8·5–10·9.	11·0–13·9.	14·0–17·5.	17·6–21·8.	Above 21·8.	
A. All Samples	5	11	13	16	11	12	14	7	7	4	203
B. (1) Samples from Farms on which Copper Deficiency has been demonstrated by Experiments	21	30	11	24	8	3	0	3	0	0	37
(2) Samples from other Farms	1	7	13	15	11	14	17	8	9	5	166
C. Soil Regions—											
(1) Swan Littoral Region	13	14	9	20	11	8	9	8	6	2	64
Dandaragan and Gingin Districts	17	33	17	17	8	0	0	8	0	0	12
South Busselton District	24	20	8	28	12	4	4	0	0	0	25
(2) Darling Peneplain Region	3	20	7	10	13	14	13	3	7	10	30
(3) Frankland Region (South Coast)	0	15	22	26	19	11	7	0	0	0	27
(4) Dwarda Region	0	8	23	23	8	23	15	0	0	0	13
(5) Irwin Region	0	0	0	9	0	9	41	9	18	14	22
(6) Avon Region	2	2	21	12	7	14	9	16	14	3	43
(7) Corrigin and Merredin Regions	0	0	0	0	50	50	0	0	0	0	2
(8) Eyre Region (Esperance)	0	100	0	0	0	0	0	0	0	0	2
D. Soil Texture—											
(1) Loams	0	3	0	6	6	18	24	16	18	9	33
(2) Sandy loams	2	5	9	19	16	9	19	7	7	7	43
(3) Sands, loamy sands, and gravelly sandy soils	7	16	18	18	8	11	10	5	5	2	119

Interval increases in geometric progression—Factor × 1·2.

TABLE 2.

COPPER CONTENTS OF SAMPLES OF OATS, WHEAT, AND BARLEY.

Distribution Table showing Percentage of Samples in each Range.

Foliage Sampled 6 to 9 weeks after Planting and Grown without Copper Fertiliser on Properties representing generally the Lighter types of Soil in the Wheat and Contiguous Districts of Western Australia.

Samples.	Range of Copper Contents—p.p.m. Dry Material.									No. of Samples.
	1·0–2·0.	2·1–3·2.	3·3–4·6.	4·7–6·4.	6·5–8·4.	8·5–10·9.	11·0–13·9.	14·0–17·5.	Above 17·5.	
All Samples	11	11	23	18	12	12	11	0	2	56
Farms where copper deficiency is not established	0	5	22	20	18	18	15	0	2	40
From copper deficient farms	38	25	25	12	0	0	0	0	0	16
From Dandaragan	75	13	12	0	0	0	0	0	0	8

Interval increases in geometric progression—Factor × 1·2.

TABLE 3.

MANGANESE CONTENT OF SUBTERRANEAN CLOVER LEAVES ON WESTERN AUSTRALIAN SOILS.

Distribution Table showing Percentage of Samples in each Range.

Samples.	Range of Manganese Contents—p.p.m. Dry Material.									No. of Samples.
	21–32.	33–46.	47 64.	65–84.	85- 109.	110–139.	140–175.	176–218.	Above 218.	
All samples	3	17	18	19	17	10	9	5	2	93

Interval increases in geometric progression—Factor × 1·2.

TABLE 4.

MANGANESE CONTENTS OF SAMPLES OF OATS, WHEAT, AND BARLEY.

Distribution Table showing Percentage of Samples in each Range.

Foliage Sampled 6 to 9 weeks after Planting and Grown without Manganese Fertiliser on Properties representing generally the Lighter types of Soil in the Wheat and Contiguous Districts of Western Australia.

Samples.	Range of Manganese Contents—p.p.m. Dry Material.									No. of Samples.
	20–32.	33–46.	47–64.	65–84.	85–109.	110 139.	140–175.	176–230.	Above 230.	
All samples	6	3	9	18	25	9	12	3	15	33

Interval increases in geometric progression—Factor × 1·2.

TABLE 5.

ZINC CONTENT OF SUBTERRANEAN CLOVER LEAVES ON WESTERN AUSTRALIAN SOILS NOT FERTILISED WITH ZINC.

Distribution Table showing Percentage of Samples in each Range.

Samples.	Range of Zinc Contents—p.p.m. Dry Material.									No. of Samples.
	10–16.	17–21.	22–27.	28–34.	35–42.	43–52.	53–64.	65–78.	79–95.	
All samples	14	9	24	13	23	9	3	4	1	76

Interval increases in geometric progression—Factor × 1·2.

TABLE 6.

ZINC CONTENTS OF SAMPLES OF OATS, WHEAT, AND BARLEY.

Distribution Table showing Percentage of Samples in each Range.

Foliage Sampled 6 to 9 weeks after Planting and Grown without Zinc Fertiliser on Properties representing generally the Lighter types of Soil in the Wheat and Contiguous Districts of Western Australia.

Samples.	Range of Zinc Contents—p.p.m. Dry Material.					No. of Samples.
	13–18.	19–26.	27–34.	35–44.	45–56.	
All samples	37	29	14	9	11	35

Interval increases in geometric progression—Factor × 1·2.

APPENDIX A.

COPPER, MANGANESE, AND ZINC CONTENTS OF SUBTERRANEAN CLOVER LEAVES AND PETIOLES SAMPLED IN OCTOBER AND NOVEMBER WHEN PLANTS IN FULL FLOWERING.

Standards of Copper Status

1. Deficient—up to 3·0 p.p.m.
2. Subnormal—3·1 to 4·5 p.p.m.
3. Low normal—4·6 to 7·5 p.p.m.
4. High normal—7·6 to 15·0 p.p.m.
5. Rich—above 15·0 p.p.m.

SWAN LITTORAL REGION.

Sample Number.	Name of Farmer.	District.	Type of Country.	p.p.m. Dry Basis.			Copper Status.
				Cu.	Mn.	Zn.	
....	Brown†	Dandaragan	Grey brown diatomaceous loam—bluegum	2·6	....	....	Deficient
119	Brown†	Dandaragan	Reddish loose sandy soil—marri, banksia	2·2	....	....	Deficient
120	Brown†	Dandaragan	Dark brown loamy sand—Yorkgum, marri	1·8	....	....	Deficient
121	Brown†	Dandaragan	Dark brown loamy sand—Yorkgum	6·1	....	....	Low normal
122	Yathroo†	Dandaragan	Sandy soil—bluegum	4·3	92	13	Subnormal
123	Yathroo†	Dandaragan	Dark chocolate brown loamy sand—marri and bluegum	1·3	....	....	Deficient
124	Yathroo†	Dandaragan	Brown sand, clay subsoil—bluegum	16·2	....	....	Rich
125	Yathroo†	Dandaragan	Dark grey loamy sand—bluegum	2·3	53	55	Deficient
126	Yaodabbie†	Dandaragan	Brown sand on red with gravel—marri and banksia	4·6	....	....	Low normal
127	Yaodabbie†	Dandaragan	Sand soak land	7·3	....	....	Low normal
128	Mungedar*	Dandaragan	Brown sand—marri	16·1	51	22	Copper treated
129	Mungedar*	Dandaragan	Brown sand on red sand—marri and wattle	12·5	97	10	Copper treated
130	Mungedar*	Dandaragan	Brown sand on red sand—marri and wattle	5·4	85	32	Copper treated, zinc treated
131	Mungedar*	Dandaragan	Black brown loam on yellow brown clay at 5 inches	6·5	38	21	Copper treated
132	Mungedar*	Dandaragan	Black brown loam on yellow brown clay at 5 inches	5·4	36	33	Copper treated, zinc treated
71	Locke*	Muchea	Grey sand, cement subsoil—wattle, bluegum and blackboy	7·9	....	....	Copper treated
90	Fewster, A.	Muchea	Grey brown gritty sand—jarrah, marri	3·8	....	....	Subnormal
209	Rennie†	Gingin	Reddish brown sand—marri and banksia	2·2	43	12	Deficient
211	Rennie†	Gingin	Red loamy sand and gravel—marri	5·1	....	....	Low normal
213	Edgar*	"Glencoe," Gingin	Brown red sand—marri, banksia, and scrub	6·7	....	....	Copper treated
89	Woodsome Estate—Copley	Bullsbrook	Yellowish brown sandy loam—marri and wandoo	8·2	....	....	High normal
214	Copley's Bank	Upper Swan	Brown sandy loam—marri and bluegum	23·0	298	41	Rich
215	Copley's Bank	Upper Swan	Brown sand, loose—marri	20·7	....	....	Rich
208	Marshall	West Swan	Grey yellow sand—paper bark, jarrah, marri	15·1	81	46	High normal
221	Marshall	West Swan	Grey sandy soil—jarrah, marri, paperbark	5·5	79	39	Low normal
49	French	Byford	Brownish yellow gravelly sand—stunted jarrah and sheoak	12·2	88	45	High normal
50	Elliott	Serpentine	Brown loam, alluvial—marri flat	10·8	99	61	High normal
51	Middleton	Keysbrook	Gravelly soil, yellow clay subsoil—stunted jarrah	6·2	....	....	Low normal

Beck 523	....	Keysbrook	Sampled 1939	7·3	....	....	Low normal
52	45·8 miles	North Dandalup	Grey sand on yellow gravelly—sandy clay loam—stunted jarrah and marri	4·6	....	....	Low normal
53	McEncroe	North Dandalup	Grey brown sandy loam—bluegum	13·3	....	....	High normal
54	Smith	Coolup	Grey sandy rise	6·1	....	....	Low normal
55	Trickett	Coolup	Orange to yellow brown sand—jarrah and scrub	10·8	....	....	High normal
56	Flax Factory	Yarloop	Grey sandy loam—wandoo	7·4	128	40	Low normal
37/40	Hanks	Harvey	Brown loam—marri	16·1	62	....	Rich
57	Stone Bros.	Brunswick	Brown fine sandy loam—wandoo	13·7	206	45	High normal
207	Shine	Brunswick	Grey loamy sand on yellow clay—marri and bluegum	13·5	....	....	High normal
58	McLeod	Waterloo	Chocolate sandy loam on redgum bank	17·9	57	37	Rich
59	Craig	Dardanup	Chocolate clay loam—bluegum	16·6	73	42	Rich
60	Buckenarra	Crooked Brook	Yellowish grey sandy soil—marri flat	13·6	....	....	High normal
204	Abel	Boyanup	Rich brown sandy loam—bluegum and marri	17·1	....	....	Rich
61	Boyanup-Elgin	Road	Grey sandy soil—jarrah, marri	9·7	161	44	High normal
62	Scott	Statham	Bluegum, marri flat	10·9	....	....	Hogh normal
38/40	Roberts	Capel	Chocolate clay loam (1940)	17·9	106	....	Rich
63	Roberts	Capel	Bluegum flat (1941)	20·0	....	....	Rich
192	Hutton	Capel	Grey sand (wet)—marri, jarrah, Christmas tree	5·3	134	35	Low normal
64	Plaistowe	Abba River	Grey sandy soil—jarrah, marri	4·7	....	....	Low normal
186	Dawson	Vasse	Grey sand—peppermint, paperbark, marri	6·0	....	....	Low normal
29	Bell†	Vasse	Reddish powdery sandy soil—marri	1·5	....	....	Deficient
31	Bell†	Vasse	Reddish powdery sandy soil—marri	2·0	....	....	Deficient
22/40	Radford Park† (Loc. 2396)	Vasse	Grey sandy soil—jarrah :—				
23	Radford Park† (Loc. 2396)	Vasse	1940 Experiments—1940	1·1	60	....	Deficient
			1941	2·6	86	40	Deficient
25	Radford Park† (Loc. 2396)	Vasse	1941 Experiments— (a)	6·2	....	....	Low normal
27	Radford Park† (Loc. 2396)	Vasse	(b)	8·9	....	....	High normal
20	Moylan† (Loc. 2391)	Kaloorup	Powdery red sandy soil—jarrah— (a)	3·2	49	40	Subnormal
21	Moylan† (Loc. 2391)	Kaloorup	(b)	2·4	....	....	Deficient
Beck 330	....	Yelverton	Sampled 1938	8·0	....	....	High normal
34	Briggs	Metricup	Brown sandy loam—marri	12·0	37	37	High normal
Beck 343	....	Metricup	Sampled 1938	5·1	....	....	Low normal
31/40	Wilkinson†	Metricup	Greyish gravelly loamy sand—jarrah—1940	2·2	66	....	Deficient
35	Wilkinson†	Metricup	1941	5·4	....	....	Low normal
37	Wilkinson†	Metricup	Greyish gravelly loamy sand—jarrah	8·3	60	27	High normal
40	Wilkinson†	Metricup	Greyish gravelly loamy sand—jarrah	5·1	....	....	Low normal
42	Blaikie†	Cowaramup	Brown grey sand—jarrah	5·8	77	68	Low normal
....	Rapson† (Loc. 2088)	Cowaramup	Brown grey sand—jarrah	1·8	46	....	Deficient
25/40	Smith†	Bramley	Grey sand—jarrah and marri. Sampled 1940	2·7	77	....	Deficient
46	Smith†	Bramley	Control plot (1941) experiment. Sampled 1941	6·5	69	69	Low normal
45	Cooper	Margaret River	Yellow grey gravelly sand—jarrah and marri	4·4	....	....	Subnormal
Beck 476	†	Margaret River	Sampled 1939	1·2	....	....	Deficient
44	Wright*	Witchcliffe	Gravelly country—jarrah, marri	12·5	....	....	Copper treated
43	Pearson	Forest Grove	Brownish grey sandy soil—marri and karri	4·1	108	80	Subnormal
35/40	Millar†	Forest Grove	Brown sandy loam—karri and marri (1940)	1·0	41	....	Deficient

DARLING PENEPLAIN REGION.

91	Hart, E.	South Chittering	Red gravelly loam—wandoo	9·5	....	....	High normal
92	Hart, G.	South Chittering	Red loam with basic schist—marri	11·5	151	33	High normal
93	Payne	Chittering	Red loam—marri and wandoo	13·2	....	....	High normal

* Land treated with copper-containing fertilisers.

† Farms on which copper deficiency has been demonstrated by experiments.

APPENDIX A—continued.

Sample Number.	Name of Farmer.	District.	Type of Country.	p.p.m. Dry Basis. Cu.	Mn.	Zn.	Copper Status.
			DARLING PENEPLAIN REGION—*continued.*				
94	Payne	Bindoon	Red loam—wandoo	20·1	....	....	Rich
95	Stephens	Bindoon	Red gravelly loam—marri	21·3	76	28	Rich
96	Stephens	Bindoon	Brown loam, alluvial—marri	22·0	....	....	Rich
97	Christian Bros.	Bindoon	Red loam—Yorkgum and wandoo	24·8	....	....	Rich
66	Sanatorium	Wooroloo	Yellow brown gravelly sand	2·1	36	14	Deficient
150	Sanatorium	Wooroloo	Brown grey gravelly sand—jarrah, casuarina	2·5	....	....	Deficient
151	Sanatorium	Wooroloo	Yellow grey gravelly loamy sand—jarrah and marri	0·9	58	13	Deficient
152	Sanatorium	Wooroloo	Green clover- grey gravelly loamy sand	2·6	....	....	Deficient
153	Sanatorium	Wooroloo	Yellow clover—grey gravelly loamy sand	2·1	....	....	Deficient
193	Fry	Donnybrook	Grey chocolate loam—phalaris good	12·6	129	31	High normal
194	Wright	Kirup	Brown loam of marri hill type	31·9	85	65	Rich
195	Wright	Kirup	Red brown loam and stones—marri	11·9	....	....	High normal
36/40	....	Bridgetown	Red loam—marri	15·8	49	....	Rich
202	Cuming	Mayanup	Grey sandy granitic soil—marri, jarrah	8·2	....	....	High normal
203	Cuming	Mayanup	Grey gritty sandy loam—jarrah, blackboy, wandoo	5·2	....	....	Low normal
9	Farleigh	Mayanup	Lateritic soil—jarrah, marri, blackboy	3·2	27	49	Subnormal
Beck 497	Forrest	Mayanup	Gravelly soil—jarrah. Sampled 1939	4·3	....	....	Subnormal
12	Forrest	Mayanup	Medium dark loam—redgum and blackboy	4·8	....	....	Low normal
205	....	Wilga	Grey sandy loam on gravel subsoil—tall jarrah and marri	8·9	....	....	High normal
206	....	Wilga	Grey sandy loam, gravel subsoil- bluegum, marri, paperbark	7·3	....	....	Low normal
201	Morgan	Dingup	Dark chocolate loam—marri, blackbutt, jarrah	9·2	....	....	High normal
196	Shepherd	Manjimup	Brownish gravelly soil—jarrah, marri	3·8	....	....	Subnormal
197	Shepherd	Manjimup	Brownish gravelly soil—jarrah, marri—west paddock	6·6	....	....	Low normal
17/40	Hall	Yanmah	Gravelly sand—jarrah	10·8	66	....	High normal
199	Hall	Yanmah	Gravelly sandy loam—jarrah, marri	6·9	....	....	Low normal
86	Hall	Yanmah	Gravelly sandy loam—jarrah and marri	3·2	66	16	Subnormal
198	Runge	Yanmah	Brown sandy soil—jarrah and marri	4·7	....	....	Low normal
233	Pardelup Prison Farm*	Mt. Barker	Grey sandy loam—jarrah and marri	9·2	71	23	Copper treated
234	Pardelup Prison Farm*	Mt. Barker	Grey gritty soil—jarrah and marri	15·2	....	....	Copper treated
			FRANKLAND REGION.				
200	Emery	Middlesex	Red loam—karri, marri	12·8	45	37	High normal
85	Doyle	Jardee	High level karri and marri country—brown sandy loam	3·8	82	22	Subnormal
247	Angel	Jardee	Brown sandy loam—karri	8·4	47	26	High normal
250	Hunter	Pemberton	Reddish brown sandy loam—karri	8·8	33	31	High normal
1/40	McRitchie	Northcliffe	Brown yellow gravelly sand—jarrah, karri	6·6	94	....	Low normal
18/40	Willis	Northcliffe	Grey and brown sand—(a)	8·4	48	....	High normal
14/40	Willis	Northcliffe	(b)	5·5	36	....	Low normal
72	Jordan	South Napier	Sandy soil—jarrah and marri	4·3	....	....	Subnormal
73	Jordan	South Napier	Poor grey sandy slope	4·4	....	....	Subnormal
74	Jordan	South Napier	Grey sandy soil	5·0	76	27	Low normal
75	Manton	South Napier	Gravelly sandy loam on yellow clay	2·9	....	....	Deficient
241	Norman†	Many Peaks, Albany	Brown clay loam on marl—yate and marri	4·9	63	16	Low normal
245	Norman†	Many Peaks, Albany	Grey sandy loam on marl—marri	4·3	....	....	Subnormal
80	Norman†	Many Peaks, Albany	Brown sandy loam—marri, yate	2·5	....	....	Deficient
76	Research Station	Denmark	Brown loam—karri	4·9	39	22	Low normal

77	Research Station	Denmark	Grey sandy country—karri—good subterranean clover	8·1	39	26	High normal
78	Tame (Loc. 412)	Denmark	Brown loamy soil—good karri country	11·3	....	....	High normal
79	Hard (Loc. 2019)	Denmark	Clay flat—tall subterranean clover growing in bracken	9·1	....	....	High normal
81	Smith (Loc. 551)	Mt. Shadforth	Brown Wakundup soil—karri	5·3	38	26	Low normal
83	Gardner	Shadforth Road		7·0	77	27	Low normal
82	Daly	Young's Siding	Grey brown sandy loam—paperbark, kingia, and scrub flat	2·5	105	....	Deficient
84	Knapp	Torbay		10·5	....	....	High normal
20/40	Steele†	Walpole	Greyish yellow brown, very gravelly loamy sand—(a)	3·1	35	....	Subnormal
13/40	Steele†	Walpole	Greyish yellow brown, very gravelly loamy sand—(b) Sampled 1940	6·3	26		Low normal
229	Steele†	Walpole	Greyish gravelly loamy sand—karri, tingle and wattle. Sampled 1942	4·8	....	....	Low normal
230	Hatfield	Walpole	Gravelly slope—karri, jarrah, marri	3·8	....	....	Subnormal
231	Cooper*	Walpole	Grey gravelly soil—marri, karri	14·8	....	....	Copper treated
232	Cooper†	Walpole	Grey gravelly soil—marri, karri	4·6	....	....	Low normal

DWARDA REGION.

67	Trott	Baker's Hill	Grey granitic soil, some ironstone gravel—wandoo and jam—(a) Dwalganup strain	3·0	52	18	Deficient
68	Trott	Baker's Hill	(b) Midseason strain	5·0	....	....	Low normal
148	Tognolini	Baker's Hill	Grey to brown-yellow gravelly sandy loam on yellow subsoil—wandoo	6·9	....	....	Low normal
149	Tognolini	Koojedda	Brown-grey sandy loam—wandoo and marri	5·4	....	....	Low normal
164	102-mile Peg	Williams	Gritty loamy sand—York and floodgum, jam	11·9	....	....	High normal
165	128-mile Peg	Albany Road	Gravelly loamy sand—jarrah, wandoo, parrot bush	3·5	....	....	Subnormal
166	Fowling	Congeling	Gravelly loamy sand—jam, wandoo, sheoak	12·9	....	....	High normal
167	Kojonup Road	Boyup Brook	Loamy sand—jarrah, marri, blackboy	3·7	....	....	Subnormal
5	Narrogin School of Agriculture	Narrogin	Sandy loam—marri, floodgum, Yorkgum	4·1	102	36	Subnormal
10	Higham	Narrogin	Sandy loam—jam, sheoak, wandoo	4·8	112	18	Low normal
6	Partridge	Kojonup	Loam—jam, wandoo, floodgum	10·7	63	35	High normal
7	Warren Bros.	Kojonup	Light sandy loam—jam, wandoo, floodgum	10·5	100	26	High normal
11	Walters	Cranbrook	Heavy clay loam—jarrah, wandoo, blackboy	9·0	53	17	High normal

IRWIN REGION.

160	Husband	Northampton	Brown loamy sand—jam	12·9	....	....	High normal
15	Teakle	Isseka	Red-brown sandy loam—jam country	18·6	177	40	Rich
16	Chapman Research Station	Nabawa	Red-brown sandy loam—jam country	11·8	174	28	High normal
158	Preston Bros.	Moonyoonooka	Loam—jam and wattle	13·2	....	....	High normal
13	Wells	Mingenew	Brown sandy loam—jam and Yorkgum	13·5	177	43	High normal
14	Wells	Mingenew	Yellowish-grey sandplain	9·8	....	....	High normal
87	Williamson	Three Springs	Dark brown clay loam	14·0	86	27	High normal
159	Chappell	Winchester	Loam—salmon gum	5·9	....	....	Low normal
161	Elliott	Watheroo	Salmon gum and wandoo	12·2	....	....	High normal
8	Seymour	Miling	Red-brown sandy loam—Yorkgum and jam	5·1	212	27	Low normal
113	Kelsall	Berkshire Valley	Light brown gritty sand—jam	12·7	246	24	High normal
114	Kelsall	Berkshire Valley	Brown sandy loam to sandy clay loam—Yorkgum, salmongum	22·2	....	....	Rich
115	Kelsall	Berkshire Valley	Light brown to brown loamy sand—jam and sheoak	21·3	....	....	Rich
116	Kelsall	Berkshire Valley	Rich brown heavy loam dolerite—Yorkgum	19·0	110	34	Rich
117	Kelsall	Berkshire Valley	Brown loamy sand, granitic—jam	24·4	....	....	Rich
118	Kelsall	Berkshire Valley (Prye)	Sand—wandoo and scrub to poor jam	11·7	....	....	High normal
112	Sandland	Walebing	Red brown loamy sand—jam	18·4	....	....	Rich

* Land treated with copper-containing fertilisers.

† Farms on which copper deficiency has been demonstrated by experiments.

APPENDIX A—continued.

Sample Number.	Name of Farmer.	District.	Type of Country.	.m. Dry Basis. Cu.	Mn.	Zn.	Copper Status
			IRWIN REGION—*continued.*				
111	Lefroy	Walebing	Rich red brown sandy loam, dolerite—jam and Yorkgum	17·1	124	38	Rich
109	Cross	0·9 miles south of Walebing	Yellow grey gravelly sand—wandoo, jam	9·4	134	16	High normal
110	Cross	Walebing	Yellow brown gravelly loamy sand—wandoo and scrub	13·8	46	20	High normal
133	Cross	Walebing	Brown gravelly sandy loam on red clay subsoil, dolerite outcrops—wandoo	30·2	....	....	Rich
134	Cross	Walebing	Yellow grey sand, some gravel, granite outcrops—wandoo and scrub	11·4	....	....	High normal
			AVON REGION.				
98	Moore	New Norcia	Yellow brown fine gravel, sandy loam, reddish clay subsoil—marri	13·9	....	....	High normal
99	Clune	New Norcia	Brown loamy coarse sand—Yorkgum and marri	16·1	....	....	Rich
100	Clune	New Norcia	Brown loamy coarse sand—Yorkgum and marri	16·6	179	30	Rich
101	Clune	New Norcia	Brown gritty loam, dolerite outcrops—Yorkgum	14·9	77	32	High normal
102	Clune	New Norcia	Dark brown loam—floodgum	20·4	....	....	Rich
103	Benedictine Community	New Norcia	Brown loamy sand—jam	20·0	....	....	Rich
104	Edgar	New Norcia	Brown loamy sand—jam and Yorkgum	14·8	....	....	High normal
105	Edgar	New Norcia	Yellow brown sand—wandoo, stinkwood, tamma	7·2	....	....	Low normal
106	Saleeba	Waddington	Brown gravelly loamy soil—wandoo, Yorkgum	4·2	....	....	Subnormal
107	Saleeba	Waddington	Brown gritty loamy sand—jam	14·3	....	....	High normal
108	Essex	Waddington	Light brown gritty loamy sand—jam and Yorkgum	18·7	....	....	Rich
135	Kennedy	Piawaning	Light yellow brown sand, some gravel—wandoo and scrub	6·2	....	....	Low normal
136	Duggan, J. J.	Yericoin	gravelly heath country	5·8	174	20	Low normal
137	Duggan, J. J.	Yericoin	Light brown loam—salmongum	18·8	....	....	Rich
138	Duggan, J. J.	Yericoin	Brown sandy loam—morrel and salmongum	16·3	64	28	Rich
139	Duggan, A. R.	Yericoin	Greyish yellow sand, some gravel—wandoo, tamma	16·9	....	....	Rich
140	Duggan, T. P. W.	Yericoin	Very gravelly sand—wandoo, parrot bush	7·8	....	....	High normal
156	Paddison	Yericoin	Gritty gravelly sand—wandoo	4·6	....	....	Low normal
157	Paddison	Yericoin	Deep loose grey sand—tussock grass and scrub	3·0	....	....	Deficient
141	Halse	Calingiri	Yellow brown gravelly sand—wandoo, jam, and scrub	5·3	....	....	Low normal
142	Lindsay	Calcarra	Brown grey gritty sand near salty creek	8·8	....	....	High normal
143	Phillips	Culham	Dark brown loamy sand, clay sub-granitic and dolerite boulders	13·3	173	31	High normal
144	Phillips	Culham	Dark brown loamy sand on yellow clay—jam and Yorkgum	18·6	....	....	Rich
145	Phillips	Coondle	Dark brown to red brown loamy sand on yellow stony clay—granitic	22·8	....	....	Rich
146	Groves	Toodyay	Grey brown heavy sandy loam, slightly moist	17·8	....	....	Rich
147	Groves	Toodyay	Brown loamy sand, brown gritty clay at 12 inches—jam	9·3	150	13	High normal
154	Ackland	Wongan Hills	Brown grey gritty loamy sand—tamma, scrub	9·5	....	....	High normal
155	Ackland	Wongan Hills	Brown grey gritty loamy sand—tamma, scrub	10·2	94	21	High normal
69	Wongan Hills Research Station	Wongan Hills	Gritty sandy soil, scrub plain	3·9	90	24	Subnormal
70	Wongan Hills Research Station	Wongan Hills	Greyish yellow sand, heath country	4·5	....	....	Subnormal
88	Smart	Korraling	Yellow sand heath	9·0	....	....	High normal
1	Research Station	Avondale	Gritty sandy loam—wandoo and jam	11·8	130	35	High normal
2	Research Station	Avondale	Dark loam near creek—Yorkgum and jam	11·9	61	42	High normal
169	Adams	Northam	Light sand—Christmas tree	3·5	....	....	Subnormal

170	Adams	Northam	Brown loamy sand	4·4	149	12	Subnormal
171	Adams	Northam	Brown and loamy sand	3·8	29	15	Subnormal
172	Brown, G. W.	Greenhills	Light soil—wandoo, blackboy, scrub	1·4	....	....	Deficient
17	Reynolds	Meckering	Yellowish grey sand carrying scrub	6·2	166	43	Low normal
4	Plant	Noman's Lake	Sandy loam—jam and wandoo	5·0	74	25	Low normal
218	Plant	Noman's Lake	Sandy loam—jam and wandoo	4·1	....	....	Subnormal
216	Milne	Borden		3·4	....	....	Subnormal
217	Metzke	Yornaning		6·6	....	....	Low normal
168		Boyerine	Sandy soil—wandoo, jam, pin grass	9·7	....	....	High normal
			CORRIGIN AND MERREDIN REGIONS				
18	Research Station	Merredin	Brown clayey loam—salmon gum, gimlet	6·9	66	37	Low normal
3	Larke	Corrigin	Yellow-brown loamy sand—scrub	9·0	118	27	High normal
			EYRE REGION.				
219	Light	Gibson's Soak	Grey sand—chittick, Christmas tree, scrub	2·9	58	25	Deficient
220	Pine Plantation	Esperance	Grey sand, gravelly clay subsoil—chittick, Christmas tree, scrub	2·9	....	....	Deficient

* Land treated with copper-containing fertilisers.

† Farms on which copper deficiency has been demonstrated by experiments.

APPENDIX B.

COPPER, MANGANESE, AND ZINC CONTENTS OF YOUNG OATS, WHEAT (W), AND BARLEY (B), REPRESENTING SOIL CONDITIONS IN THE WHEAT AND CONTIGUOUS DISTRICTS OF WESTERN AUSTRALIA. PLANTING RANGED FROM MARCH TO LATE JUNE AND SAMPLING BETWEEN 19TH JUNE AND 11TH AUGUST (CHIEFLY IN MONTH OF JULY). SAMPLING RANGED FROM SIX TO NINE WEEKS AFTER SEEDING IN MOST CASES.

(*Note.—Samples not designated* (W) *or* (B) *are Oats.*)

Sample No.	Farmer.	District.	Soil and Vegetation.	p.p.m. dry basis.		
				Cu.	Mn.	Zn.
62	A. Robb	Northampton	Jam—red brown sandy loam	12·8	104	23
94	Drage Bros.	Northampton	Scrub plain	7·9	....	22
1W	Teakle	Isseka	Heath—sand	7·4	113	18
95	M. Royce	Greenough		3·9	....	18
60	Burges	Irwin	Yorkgum—red brown sandy loam	6·8	183	24
8W	Pope Bros.*	Caron	Heath—sand and gravel (a)	2·5	96	24
9W	Pope Bros.*	Caron	Heath—sand and gravel (b)	3·0	....	....
32	Pope Bros.	Carnamah	Heath—sand and gravel	3·6	97	16
35	G. McAlpine	Latham	Mallee	10·1	73	33
36	W. McAlpine	Latham	Heath	3·2	119	19
33	I. Roberts	Coorow	Scrub	5·9	94	37
37	J. P. Meehan	Coomberdale	Salmon and gimlet	11·9	57	16

APPENDIX B—continued.

Sample No.	Farmer.	District.	Soil and Vegetation.	p.p.m. Dry Basis.		
				Cu.	Mn.	Zn.
38	J. P. Meehan	Coomberdale	Jam, Yorkgum	3·7	....	....
39	J. P. Meehan	Coomberdale	Jam, Yorkgum	3·3	....	....
4B	Herley Bros.	Gunyidi	Heath—sand on quartzite (a)	9·4	25	14
5B	Herley Bros.	Gunyidi	Heath—sand on quartzite (b)	5·1	....	....
34	....	Miling	Yorkgum	10·8	91	17
65	Yaodabbie*	Dandaragan	Marri—red sand (a)	1·4	94	16
68	Yaodabbie*	Dandaragan	Marri—red sand (b)	1·5	149	20
16	J. A. V. Brown* (Experiment A)	Dandaragan	Bluegum—brown diatomaceous loam (a)	1·5	234	45
19	J. A. V. Brown* (Experiment A)	Dandaragan	Bluegum—brown diatomaceous loam (b)	1·2	....	..
20	J. A. V. Brown* (Experiment A)	Dandaragan	Bluegum—brown diatomaceous loam (c)	0·9	....	....
23	J. A. V. Brown* (Experiment C)	Dandaragan	Bluegum—brown diatomaceous loam (d)	1·9	98	18
12	Mungedar*	Dandaragan	Marri—brown sand (a)	4·1	33	16
14	Mungedar*	Dandaragan	Marri—brown sand (b)	3·0	....	....
63	C. H. Smith	Koorda	Wodjil—sand and gravel	3·5	....	....
24W	S. Williams*	Hindmarsh (*via* Dowerin)	Heath—sand and gravel	4·2	151	26
26	S. Williams*	Hindmarsh (*via* Dowerin)	Heath—sand and gravel	4·3	....	....
27	....	Kellerberrin	Sheoak, scrub	2·5	68	15
29	....	Kellerberrin	Sheoak, scrub	10·4	....	....
48W	Research Station	Merredin	Wodjil—sand and gravel	5·5	237	19
51W	Research Station	Merredin	Wodjil—sand and gravel	12·8	....	....
40W	A. P. Carmody*	Jilakin	Wodjil—gravelly sand (a)	3·9	235	18
42W	A. P. Carmody*	Jilakin	Wodjil—gravelly sand (b)	2·8	....	....
44W	Bebbington Bros.*	Bullaring	Wandoo and scrub—sand on gravelly subsoil (a)	6·3	97	53
46W	Bebbington Bros.*	Bullaring	Wandoo and scrub– sand on gravelly subsoil (b)	5·6	....	....
83	J. C. Trott	Corrigin	Scrub—sand and gravel	12·0	56	43
84	L. Cousins	Bulyee	Wattle and tamar—sand (a)	8·1	....	....
85	L. Cousins	Bulyee	Sheoak, jam, Yorkgum—loamy sand (b)	5·3	120	24
86	C. G. Russell	East Wickepin	Wandoo, etc.—sandy (a)	8·1	81	18
87	C. G. Russell	East Wickepin	Scrub—gravelly sand (b)	10·3	....	....
93B	W. W. Howard	East Wickepin	Sheoak, jam, wandoo—gravelly sand	3·6	22	17
88	M. Green	Toolibin	Wandoo, mallee—sand	5·4	70	25
89	A. Murray	Tinkurrin	Mallee—gravelly sand	7·0	75	39
76	W. H. Bucholz	Katanning	Wandoo—gravelly	6·3	142	30
77	M. W. Ball	Katanning	Marri, jam—gravelly sand	3·5	....	....
75	W. Lloyd Wood	Pallinup	Yorkgum—sandy loam	13·1	50	50
74	R. M. Watterson	Gnowangerup	Mallee—sandy	3·5	....	....
90	A. G. Kingston	South Borden	Wandoo, jam—quartzy sand (a)	6·8	73	31
91	A. G. Kingston	South Borden	Wandoo, jam—quartzy sand (b)	20·0	143	27
92	A. G. Kingston	South Borden	Wandoo, jam—quartzy sand (c)	8·7	....	....
78	H. Brockman	Muradup	Marri—loamy sand (a)	12·7	325	53
79	H. Brockman	Muradup	Marri—poor sand (b)	9·0	....	....
80	Benn Bros.	Boscabel	Wandoo, jam—sandy	4·6	....	....
82	E. Fairweather	Tambellup	Mallee, wandoo—gravelly sand	5·1	....	....
81	F. E. Hitchins	Cranbrook	Yate—sandy	5·4	248	32

* Farms on which copper deficiency has been demonstrated by experiments.

ACKNOWLEDGMENTS.

The authors wish to acknowledge with thanks the assistance of Messrs. W. M. Nunn, A. S. Wild, F. V. Knapp, A. B. Adams, G. N. Lowe, G. H. Burvill, H. G. Elliott, N. Davenport, and others, in the collection of samples, and of the Chief Draftsman of the Lands Department in the preparation of the map.

LITERATURE CITED.

Beck, A. B. (1941): *Jour. Agric. West. Aust.*, 18 : 285-300.

Beeson, K. C. (1941): U.S.D.A. Misc. publ., 369.

Bennetts, H. W. (1942): *Jour. Agric. West. Aust.*, 19 : 7-13.

Bennetts, H. W., and Beck, A. B. (1942): *C.S.I.R. (Aust.), Bull.* 147.

Bennetts, H. W., and Chapman, F. E. (1937): *Aust. Vet. Jour.*, 13 : 138.

Bennetts, H. W., Harley, R., and Evans, S. T. (1942):—

(a) *Aust. Vet. Jour*, 18 : 50-63.

(b) *Jour. Agric. West. Aust.*, 19 : 96-104.

Carne, W. M. (1927): *Jour. Agric. West. Aust.*, 4 : 515-519.

Dunne, T. C. (1938): *Jour. Agric. West Aust.*, 15 : 120-126 and 381-382.

Filmer, J. F., and Underwood, E. J. (1936): *Jour. Agric. West Aust.*, 13 : 199-201.

Kessell, S. L., and Stoate, T. N. (1938): *Pine Nutrition*, Forests Dept. of W.A. Bull. No. 50.

Pittman, H. A. (1935): *Jour. Agric. West Aust*, 12 : 196.

Teakle, L. J. H. (1938): *Jour. Roy. Soc. West Aust.*, 24 : 123-195.

Teakle, L. J. H. (1942): *Jour Agric. West Aust.*, 19 : 242-253.

Teakle, L. J. H., and Wild, A. S. (1940): *Jour. Agric. West Aust.*, 17 : 223-233.

Underwood, E. J., and Filmer, J. F. (1935): *Aust. Vet. Jour.*, 11 : 84-92.

Wickens, G. W. (1924): Report of Proceedings of Imperial Botanical Conference, London, 353-357.

Vegetable Seed Production.

THE SIGNIFICANCE OF CROSS-POLLINATION.

G. R. W. MEADLY.

The increased interest in vegetable seed production has directed attention to those plants which are likely to hybridise when grown in proximity. A pedigreed crop, due to accidental crosses, may give rise to seed which will produce plants of undesirable types. Thus the results of many years breeding may be nullified in one season.

The risk of such a happening varies considerably with different plants and is influenced by their mode of pollination. It is difficult to group plants under this heading as different varieties or even strains of the same variety may differ considerably in the extent to which self or cross-pollination occurs. External factors such as seasonal conditions may influence the results. For convenience, however, the following general grouping may be made:—

1. Naturally self-pollinated.
2. Naturally cross-pollinated.
3. Flowers of one sex only on individual plants.

These groups are by no means well defined as cross-pollination often occurs with plants which are naturally self-pollinated while the converse is true for the second group. Again plants which are normally dioecious, i.e., bear flowers of one sex only on individual plants, at times have both sexes represented on the same plant.

Obviously cross-pollination is the normal function of many plants, but the difficulty in connection with seed production arises when crosses occur between plants of different types and result in the introduction of undesirable features. The risk of cross-pollination of this nature is greatest when related types of naturally cross-pollinated plants are growing together, although the possibility cannot be dissociated entirely from plants that are naturally self-pollinated. Varieties of cabbage, a "group 2" plant, cross readily but even with peas, which are naturally self-pollinated, artificial hybridisation between varieties can be effected easily and there is a risk, although small, of accidental crossing.

Besides being affected by the mode of pollination, the chances of cross-pollination between plants of different types are influenced to a great extent by the botanical relationships of the plants concerned. To generalise, strains and varieties cross readily, e.g., (*Brassica oleracea var. capitata*) cabbage and kohl-rabi (*B. oleracea var. caulo-rapa*); species less frequently, e.g., turnip (*B. campestris var. rapa.*) and Chinese cabbage (*B. chinensis*); while crosses between different genera are rare, e.g., cabbage (*Brassica oleracea var. capitata*) and radish (*Raphanus sativus*).

For the guidance of vegetable growers a table has been prepared showing:—

1. The "mode of pollination" group.
2. Plants likely to cross-pollinate naturally.
3. Plants which may cross-pollinate naturally but with which crossing is unlikely to be frequent.
4. Plants which are very unlikely to cross-pollinate naturally.

In many cases where there is no information available concerning the possibility of natural cross-pollination, the plants have been grouped according to the behaviour of their affinities. The following notes supplement the information contained in the table:—

1. Many attempts have been made to secure interspecific hybrids within *Phaseolus*, mostly without success except for that involving the French bean (*P. vulgaris*) and the runner bean (*P. multiflorus*). Being self-pollinated however, the risk of appreciable natural cross-pollination is not great.

2. The beet flower is largely wind pollinated and cross fertilization can be effected in areas twelve or more miles apart.

3. *Brassica oleracea* contains the cabbage, cauliflower, borecole, broccoli, brussels sprouts, kale and kohl-rabi, and there is evidence to show that many members of this cabbage group freely intercross when in close proximity at flowering time.

4. The carrot is an example of a protandrous plant, that is, one in which the anthers shed their pollen before the stigma is receptive to pollen. Consequently self-pollination is possible only when the stigmas of the older flowers can be served by the pollen from the younger ones. Failure of isolated umbels to set seed has been due to this protandry.

5. There is a general impression that the cucumber (*Cucumis sativus*) will cross with *C. melo* which includes the musk melons and rock melons or cantaloupes, but experiments do not support this impression.

6. The onion, *Allium cepa* has been crossed with *A. fistulosum* in order to incorporate some of the disease and insect resistant characters of that species. The possibility of crosses between the onion, leek (*A. porrum*) and other onion like plants such as garlic (*A. sativum*) must not be overlooked, although local experience indicates that brown and white onions do not cross readily.

7. The differentiation of pumpkins, squashes and marrows is very uncertain because, as popularly classified, they are included in three species, *Cucurbita pepo, C. moschata* and *C. maxima*. Contrary to popular belief those belonging to different species practically never cross naturally, but varieties of the same species cross very readily. As all three vernacular names are at times, applied to varieties of the same species, as a general rule, when intended for seed purposes, pumpkins, squashes and marrows should not be grown in close proximity. There is no evidence to support the popular belief that pumpkins and water melons should not be grown together because of the immediate effect of cross-pollination.

8. Although peas are naturally self-pollinated, artificial hybridisation between the field and garden pea types can be effected easily and the possibility of a small proportion of accidental crosses must be considered.

9. Although the risk of radish crossing with cabbage or other varieties of *Brassica oleracea* is not very great, an actual radish-cabbage cross is on record, and consequently precautions should be taken.

10. Successful crosses have not been effected between turnip and radish or cabbage, but the turnip has been crossed with the Chinese cabbage (*Brassica chinensis*) and the swede.

11. Certain weeds are known to cross with crop plants, and cause a deterioration of type. Crosses are easily made between wild radish (*Raphanus raphanistrum*) and cultivated radish (*R. sativus*) while weed species of *Brassica* such as field brassica (*B. campestris*) and charlock (*B. sinapistrum*) are likely to cross with some of the cabbage group.

The wild carrot (*Daucus spp.*) must be considered when growing carrots for seed.

In preparing the table and supplementary information, frequent references have been made to:—

Botany of Crop Plants: W. W. Robins, 1924.

Breeding Crop Plants: H. K. Hayes and R. J. Garber, 1927.

Year Book of Agriculture: United States Department of Agriculture, 1937.

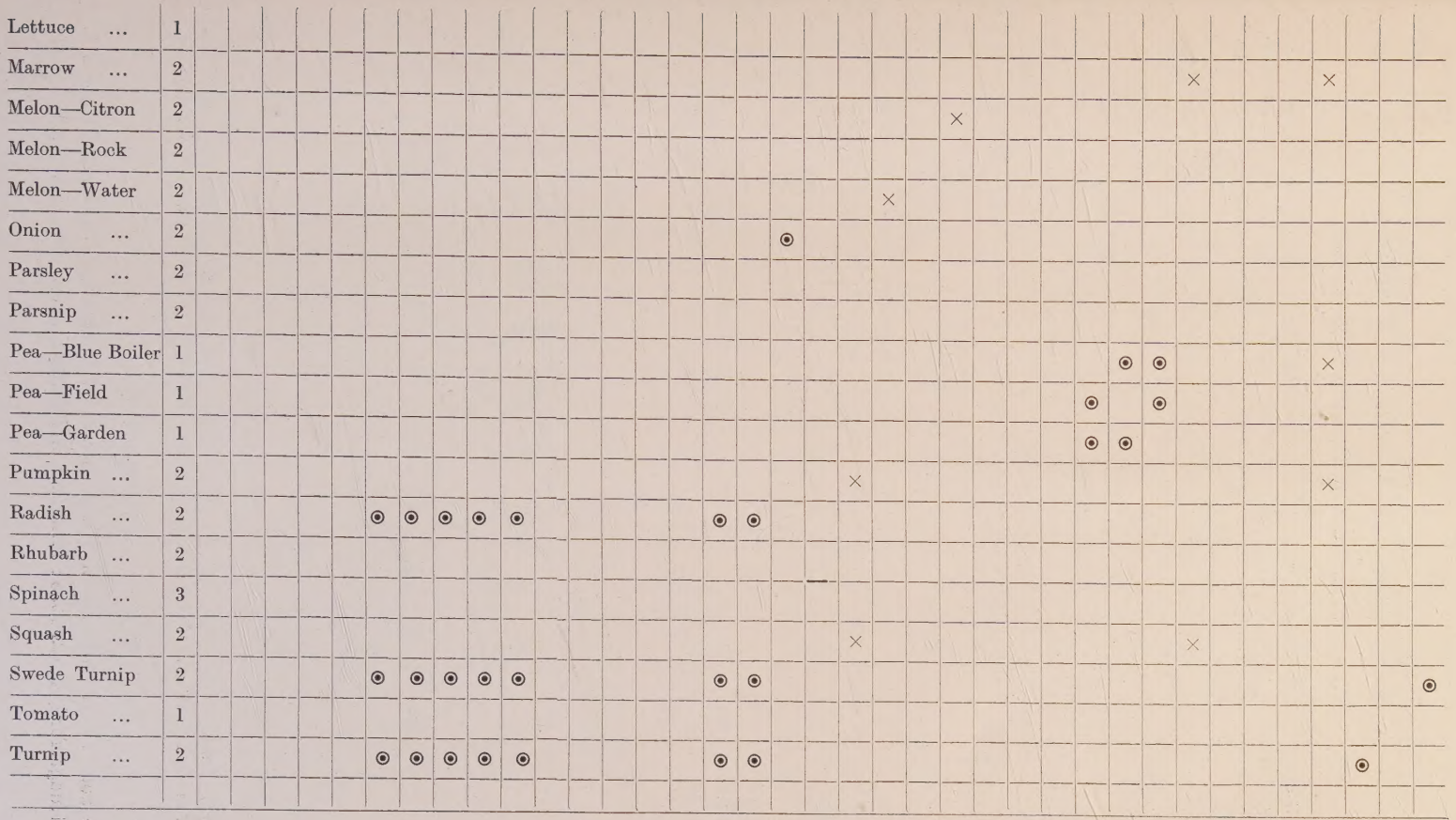
SUMMARY.

When growing vegetables for seed purposes, strains and varieties of the same plant, especially if they are naturally cross-pollinated, should not be grown together.

The plants linked by symbols in the table should not be grown in proximity and particular care should be taken with those linked by a cross.

Plants likely to cross-pollinate naturally should be grown at least one half mile apart. With wind pollinated plants such as beets, a considerably greater distance is advisable. Care should be taken to destroy all weeds likely to cross with the crops being grown.

	Method of Pollination	Bean—Broad	Bean—French	Bean—Runner	Beet—Red	Beet—Silver	Borecole	Broccoli	Brussel Sprouts	Cabbage	Cauliflower	Carrot	Celery	Cress—Garden	Cress—Water	Cucumber	Kale	Kohl-rabi	Leek
Bean—Broad	1																		
Bean—French	1																		
Bean—Runner	1																		
Beet—Red	2																		
Beet—Silver	2																		
Borecole ...	2																		
Broccoli ...	2																		
Brussel Sprouts	2																		
Cabbage ...	2																		
Cauliflower	2																		
Carrot ...	2																		
Celery ...	2																		
Cress—Garden	2																		
Cress—Water	2																		
Cucumber ...	2																		
Kale ...	2																		
Kohl-rabi ...	2																		
Leek ...	2																		
Lettuce																			
Marrow																			
Melon—Citron																			
Melon—Rock																			
Melon—Water																			
Onion																			⊙
Parsley																			
Parsnip																			
Pea—Blue Boiler																			
Pea—Field																			
Pea—Garden																			
Pumpkin																			
Radish							⊙	⊙	⊙	⊙	⊙						⊙	⊙	
Rhubarb																			
Spinach																			
Squash																			
Swede Turnip							⊙	⊙	⊙	⊙	⊙						⊙	⊙	
Tomato																			
Turnip							⊙	⊙	⊙	⊙	⊙						⊙	⊙	
Bean—Broad																			
Bean—French							×	×	×	×	×						×		
Bean—Runner							×	×	×	×	×						×	×	
Beet—Red																			
Beet—Silver																			
Borecole ...																			
Broccoli ...																			
Brussel Sprouts																			
Cabbage ...																			
Cauliflower																			
Carrot ...																			
Celery ...																			
Cress—Garden																			
Cress—Water																			
Cucumber ...																			
Kale ...																			
Kohl-rabi ...																			
Leek ...																			
Lettuce																			
Marrow																			
Melon—Citron																			
Melon—Rock																			
Melon—Water																			
Onion																			
Parsley																			
Parsnip																			
Pea—Blue Boiler																			
Pea—Field																			
Pea—Garden																			
Pumpkin																			
Radish																			
Rhubarb																			
Spinach																			
Squash																			
Swede Turnip																			
Tomato																			
Turnip																			



POLLINATION TABLE.

1. Naturally self-pollinated.
2. Naturally cross-pollinated.
3. Flowers of one sex only on individual plants.

× Plants likely to cross-pollinate naturally.
⊙ Plants which may cross-pollinate naturally but with which crossing is unlikely to be frequent.

Ants Causing Death in Poultry.

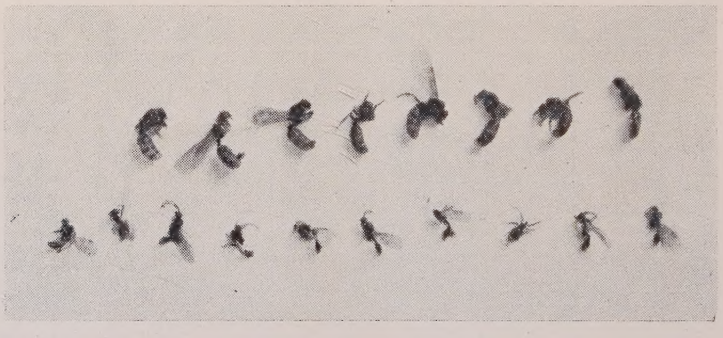
C. F. H. JENKINS, Government Entomologist.

Although at times ants may worry sitting hens or tiny chickens, they are usually considered to be of little importance to poultry keepers. In the last few years, however, several instances of fowl mortality due to the eating of ants have been reported. The most recent occurrence was reported from Dumbleyung in May when many farmers lost fowls under what appeared to them most mysterious circumstances. There was no preliminary sickness and as one correspondent described it, "the birds just dropped dead as you would blow out a candle."

An examination of the fowls' crops showed that they contained a number of reddish-brown winged ants measuring about three-eights of an inch in length and also a number of smaller ants. The ants in question are known as *Monomorium bicorne,* and unfortunately have no popular name. Although poultry mortality from eating ants is not common several species of ants have been known to cause this trouble in different parts of Australia.

The first record of mortality in Western Australia was in about 1923 when J. Clark and G. Allman investigated this matter. In all cases death appears to be caused by the large female ants. The males and workers are so small that they contain only a slight amount of poison (formic acid) and also attract but little attention. As far as I am aware the only places in the State from which trouble has been recorded are Mount Barker, Katanning, and Dumbleyung, but as the ant has a much wider distribution than this it is likely that there have been many unreported cases in other districts.

Fortunately, of course, the danger period is short, for it is only when the female ants are leaving their nests, frequently in the early winter, that they can fall a prey to fowls and other poultry.



Ants removed from crop of dead fowl.

ACKNOWLEDGMENT.

My thanks are due to Mr. J. Clark, Entomologist, National Museum, Melbourne, for the identification of the ants and for notes on its distribution, etc.

REFERENCES.

Anon., 1940: "New South Wales Agricultural Gazette," Volume 51, page 271.

Hungerford, T. G., 1939: "Diseases of Poultry in New South Wales."

Does Early Harvesting of Peas check the Pea Weevil?

A. W. GULL and A. B. ADAMS.

The subject of this note, viz. the possibility that the harvesting of peas when fully grown, but still green, may check the development of the larvae of the Pea Weevil (*Bruchus pisorum*), is queried because one experience does not prove more than the one case.

At Muresk College in the early summer of 1939 one of us (A. W. Gull) gathered the surplus Greenfeast Peas while the pods were still green, with the peas fully developed. These were dried in the pods. The peas were grown in the college garden, and a small quantity of Brunswick White Peas were grown in the grass garden adjoining.

The Brunswick White Peas were allowed to ripen on the plant and on harvest were found to be badly affected with weevil. Practically every pea had one weevil, some had two.

On examining the Greenfeasts when dry they showed no sign of weevil at the time, nor did any weevil develop subsequently.

This experience suggests that it would be well worth while for growers to mow a portion of the pea crop when the pods are full but still green, allow them to dry off on the ground and then collect and thrash in whatever way is customary.

Those harvested in this way can then be compared with those that are allowed to mature in the normal way. Should it prove that the weevil may be controlled by this procedure, it may prove a simpler and more convenient method than that now in use, viz. fumigation with carbon bisulphide.

It will be appreciated if any growers who experiment with this way of harvesting will advise the Agricultural Department of its effectiveness in weevil control.

It is possible that this early harvesting may reduce the vigour and percentage of germination. On the other hand, if they are Blue Boilers, it should benefit their cooking quality.

Agricultural Broadcasts.

The following programme of Agricultural Talks has been arranged for the October-December quarter and will be broadcast from Stations 6WN and Regionals at 9.15 p.m. each Thursday.

Date.	Talk Prepared by:	Title.	Summary.
	I.—FARMERS IN A CHANGING WORLD.		
Oct. 21	H. G. Elliott, Agrostologist, Department of Agriculture	Plant Fibres ...	A classification is given of vege table fibres together with an account of where they are mainly grown and the uses to which they are put, with special reference to flax.
Nov. 18	Dr. E. J. Underwood, Animal Nutrition Officer, Department of Agriculture	Fertility in Farm Animals	The factors which determine fertility of different kinds of farm stock and the practical means of improving fertility will be discussed.
Dec. 16	C. A. Gardner, Government Botanist, Department of Agriculture	Some Drug Plants of Australia	A talk on the materials at present in use and the potential field for investigations.

AGRICULTURAL BROADCASTS—*continued.*

Date.	Talk Prepared by:	Title.	Summary.
	II.—TOPICAL ITEMS.		
Oct. 28 Nov. 25 Dec. 23	G. K. Baron Hay, Under Secretary for Agriculture will discuss current events in agriculture		
	III.—FARMERS' FORUM.		
Oct. 7 Nov. 4 Dec. 2 Dec. 30	Discussion on topics submitted by farmers—Arranged by Dr. G. A. Currie, Professor of Agriculture, University of Western Australia		
	IV.—TECHNICAL TALKS.		
Oct. 14	C. F. H. Jenkins, Government Entomologist, Department of Agriculture	An Insect Saboteur	A brief outline will be given showing the importance of the Fruit Fly in connection with the necessity for increased food production throughout Australia. The life history and habits of the fly will be briefly touched upon, and control measures will be enumerated.
Nov. 11	I. Thomas, Superintendent of Wheat Farming, Department of Agriculture	Malting Barley ...	The importance of careful harvesting; marketing the crop.
Dec. 9	J. O'Donnell, Fire Control Officer, Forestry Department	The Annual Bush-fire Menace	The advent of summer focusses attention on the danger of damage and loss from uncontrolled fires. Diminished manpower in rural districts necessitates early and thorough organisation of prevention and control measures. It is a matter of national importance to reap the maximum returns in farm produce resulting from a good season in the agricultural areas and to minimise capital loss from fires.

By Authority: ROBERT H. MILLER, Government Printer, Perth.